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A GRAMMAR OF CHEMISTRY,

ADAPTED TO THE USE OF

SCHOOLS AND PRIVATE STUDENTS,

BY FAMILIAR ILLUSTRATIONS AND EASY EXPERIMENTS.

BY J. L. COMSTOCK, M. D.

With numerous Engravings on Wood.

SECOND EDITION.

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1825.

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Clerk of the District of Connecticut.

A true copy of Record, examined and sealed by me,
CHARLES A. INGERSOLL,
Clerk of the District of Connecticut.

B. H. NORTON, Printer.

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A GRAMMAR OF CHEMISTRY.

Definition. Chemistry is that science by which we are enabled to discover the composition and properties of bodies.

1. The object of Chemical Philosophy is to ascertain the causes of the natural changes, which take place in all substances, and to discover the laws by which those changes are governed.

2. Most of the substances belonging to our globe, are constantly undergoing alterations in a perceptible manner, and one variety of matter becomes as it were transformed into another.

Observation 1. The foundation of chemical philosophy is observation, analogy, and experiment. By observation, facts are impressed on the mind. By analogy, similar facts are connected and the existence of other unknown facts are inferred. By experiment new discoveries are made; and in the progress of knowledge, observation guided by analogy leads to experiment, while the inferences from analogy confirmed by experiment, become scientific truth.

2. The ends of this branch of knowledge, are the discovery and application of new principles, or of new substances, to the arts and comforts of life, and also to apply known substances to new and useful purposes.

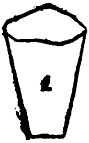
Illustration. Among the useful inventions, or improvements which have been derived from a knowledge of chemistry, we may enumerate the steam engine, the manufacture of a peculiar kind of porcelain ware, the safety lamp, a new mode of tanning, the analysis of soils, and the consequent improvements in agriculture, the detection of poisons, and adulterations; improved methods of manufacturing medicines, the discovery of new ones, new or improved methods of dyeing, a new and expeditious mode of bleaching, improvements in the arts of soap making, in manufacturing several of the metals or extracting them from their ores, of manufacturing several salts, as alum, copperas, and nitre, the discovery of several new paints, and new methods of manufacturing others. Indeed, almost all the arts of life have been in some way benefited by this science.

3. As the science of chemistry is founded on experiment, chemical knowledge is chiefly obtained by means of a set of utensils, constituting an apparatus, together with observations made on the action of *re-agents*.

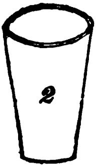
Obs. 1. It was once thought to be indispensibly necessary, that a philosophical chemist should be provided with a regular chemical laboratory, or room fitted up with furnaces, and other apparatus, on an extensive scale. This no doubt is of great utility and advantage; but the researches of Bergman, Morveau, and other eminent chemists, have shown, that many, if not most of the chemical operations may be performed with the blowpipe, a few small glass vessels, and an Argand lamp, with greater speed, perspicuity, facility, and of course, cheapness, than where larger quantities of the materials for experiment are used.

2. Without making such experiments as verify most of the fundamental principles of chemistry, the student will find that a great part of his study on this subject will be lost labour. I have therefore annexed the figures of some of the most simple chemical instruments, including only such as are easily obtained, that the student may have an early acquaintance with their shapes and uses.

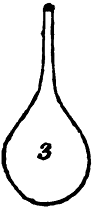
CHEMICAL UTENSILS.



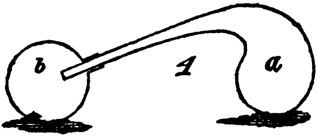
Crucibles, fig. 1, are deep conical cups, without handles. The form is triangular at the top for the convenience of pouring out, but becomes gradually round towards the bottom. They are made of clay and sand, baked hard, and will withstand a high heat without melting. They are of all capacities, from a fluid dram, to a pint. They are used for roasting ores, fusing metals, &c.



Pots, fig. 2. are made of platina, black-lead, silver, &c. and used for particular purposes, where the action of the substance to be operated on, would destroy the clay crucibles.

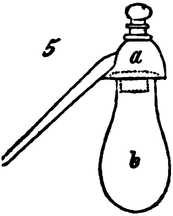


Matrasses, fig. 3, are vessels made of glass, in the shape of an egg, with a long neck. They are used for effecting the solution of such substances as require heat, or long continued digestion before they can be dissolved.



Retorts, fig. 4, *a*. are globular vessels of glass, metal, or earthen ware, with a long neck bent on one side. They are of indispensible use to the chemist for the distillation of corrosive substances, collecting the gases, &c. The *tubulated* retorts have a tube and ground stopper, where the neck and body of the retort joins.

Receivers, fig. 4, *b*, are globular glass vessels, with an opening or spout on one side, into which is inserted the neck or beak of the retort. They are necessary appendages to the retorts, and are destined to receive whatever comes over from the retort during the process of distillation, &c. They are also made in the form of a bell, for the purpose of receiving and retaining the gases.



The *alembic*, fig. 5, is used for the distillation, or sublimation of volatile substances. It consists of two parts ; viz. *a* the head ground on, and *b* the body into which the substance to be distilled is put. This part is set into a sand bath, placed over a fire. The product of distillation rises up into the head, where it is condensed, and runs down the spout into a receiver. A *cucurbit* is the body of the alembic without the head. When the head is put on it is an alembic.

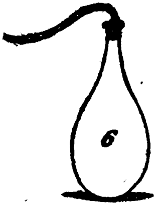


Fig. 6. A *Florence flask,* furnished with a tube to be used instead of a retort. Students will save considerable expense by using these flasks in the room of retorts. The cork is pierced with a burning iron, through which is passed a glass tube bent as in the figure. The cork must stop the mouth of the flask closely. In obtaining oxygen gas by means of sulphuric acid and manganese, and for many other processes, this answers the purpose of a retort, while if broken the expense is only a few cents.

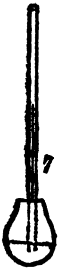


Fig. 7. *An air thermometer* for ascertaining the temperature of liquids. This is easily constructed. It consists of a thin bottle partly filled with any coloured liquid, and partly with air ; a glass tube of small bore, as a broken thermometer tube open at both ends, is either cemented, or hermetically sealed into the bottle, so that its lower extremity may nearly reach the bottom.

The expansion of the air included in the bottle, on the application of heat, drives the coloured fluid up the tube. A scale is fitted to the tube to measure the temperature. This simple instrument is convenient for measuring the comparative heat of liquids, as it will indicate changes not detected by the mercurial thermometer.

Fig. 8. The common *blow-pipe.* Every effect of the most violent heat of a furnace, may be produced by the flame of a candle, or lamp, urged upon a small particle of any substance, by this little instrument. It consists merely of a brass pipe, rather more than the eighth of an inch in diameter at one end, and tapering nearly to a point at the other. It is bent as in the figure.

To use it, place the curved end in the flame of a lamp, and apply the lips to the other end, then blow gently and steadily, giving the jet of flame a horizontal direction. To keep up a constant stream of air for a length of time, the inspiration must be made by the nostrils, while the cheeks are used as bellows. The art of doing this is soon acquired by practice. The fragment on which the flame is thrown, is laid on a piece of charcoal, held by a pair of small forceps. When a very intense heat is required and the fragment is so light as to be blown off by the air, it must be confined by making a small cavity in the charcoal support, into which the substance is put, and another piece of charcoal is placed partly over it, so as to prevent its blowing away.

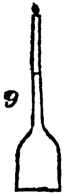
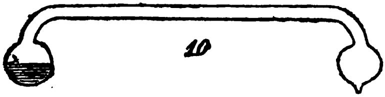
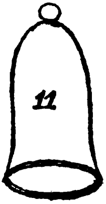


Fig. 9. *A bottle for ascertaining the specific gravity of liquids.* This is a very simple method. Take a small bottle with a long neck and weigh it accurately; then put into the bottle 1000 grains by weight of distilled water, and mark its height on the neck with a file.

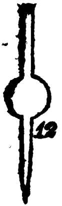
As distilled water is the standard by which the comparative weights of other substances are known, the same bulk of any other liquid, weighed at the same temperature, will give its specific gravity. Thus suppose that on filling the bottle up to the mark at which the distilled water weighed 1000 grains, with sulphuric acid, this last should be found to weigh 1850 grains; then the specific gravity of sulphuric acid is to water, as 1850 to 1000, or nearly double. If filled up to the same mark with alcohol, it might weigh 800 grains. The specific gravity of alcohol then would be 800, water being 1000; and so of any other liquid. The strength of proof spirits may be told in this way.



The Cryophorus, or *frostbearer*, fig. 10, is an invention of Dr. Wollaston's. It consists of a tube of glass, terminated at each end with a bulb, one of which is half full of water. It is perfectly exhausted of air and hermetically sealed; the consequence is that the water is always disposed to evaporate. This evaporation, however, does not proceed so fast as to freeze the water; but if the empty ball be cooled by some artificial means, so as quickly to condense the vapour which arises from the water, the heat is carried off so suddenly by the evaporation, that the water freezes. This may be done in warm weather, and affords a very curious experiment.



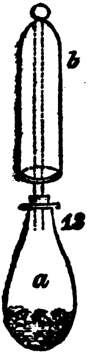
A bell glass receiver fig. 11, is of an indispensible use in making experiments upon air, or the gases. It is a glass vessel of the shape seen in the figure. The knob at the upper part is for a handle, by which it is removed. It is used for confining any kind of elastic fluid on which experiments are made. A large tumbler is a good substitute.



The *Dropping tube* fig. 12, is a glass tube blown into a ball in the middle. It is filled by putting the small end into the liquid, and exhausting the air by sucking with the mouth at the other end. The thumb is then placed on the upper orifice, which keeps the liquor from running out. On raising the thumb carefully the liquor is expelled in drops.

Obs. The ammoniacal gas cannot be collected and retained in the usual way over water, because it is immediately absorbed by that fluid. This is also the case with several of the other gases. Chemists are therefore obliged to make use of a *mercurial,* instead of a *water* bath in experimenting on these gases.

By the following method, such gases as cannot be retained by water, and are of *less specific gravity than the atmosphere,* may be collected and submitted to experiment without the aid of a mercurial bath.



Take a flask *a,* fig. 13, put into it a mixture of equal parts of slacked quicklime and muriate of ammonia, both separately reduced to a fine powder. Adapt to the mouth of the flask a cork, pierced with a hot iron, with a glass tube 10 or 12 inches high, passed through the aperture. Invert over the tube the bell-glass *b* in such a manner that the upper extremity of the tube reaches the bottom of the receiver. Then apply to the bottom of the flask the heat of a lamp.

The ammoniacal gas will be produced, in consequence of the combination which takes place between the muriatic acid of the muriate of ammonia and the quicklime; this sets the ammonia at liberty, and being lighter than atmospheric air, it rises up, expels the air from the bell glsss, and gradually takes its place. Experiments may be made on it by introducing other gases up into the receiver in the same way.

GAS APPARATUS.

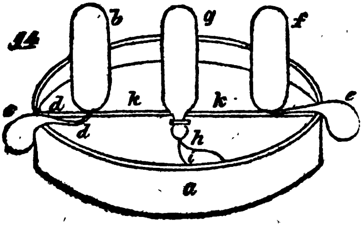


Fig. 14. The method of making experiments with permanently elastic fluids, or gases, though simple, requires some directions. We live immersed in an atmosphere not differing greatly in density from these fluids, which for this

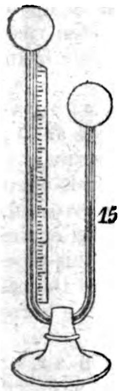
reason are not sufficiently ponderous to be detained in open vessels by their weight. The figure represents a wooden vessel, or tub; *k*, *k*, *k*, is a shelf fixed in the tub a few inches from the brim.

When this apparatus is to be used, the tub is filled with water to such a height as to rise an inch or two above the shelf; *b*, *g*, *f*, are glass jars inverted, or turned mouth downward, which rest upon the shelf. If these, or any other vessels open only at one end, be plunged under water, and then inverted, they will remain full notwithstanding they are raised out of the water, provided their mouths be kept under it: for in this case the water is sustained in the vessel by the pressure of the atmosphere, in the same manner as the mercury is in the barometer.

It may without difficulty be imagined that if common air, or any other fluid resembling common air in lightness, be suffered to enter these vessels of water from the bottom, it will rise to the upper part of the vessel, and displace the water. If a bottle or cup, or any other vessel, in that state which is usually called empty, though, it is really full of air, be plunged into the water with its mouth downward, scarce any water will enter, because its entrance is opposed by the resistance of the included air; but if the vessel be turned up, it immediately fills, and the air rises in one or more bubbles to the surface. Suppose this operation to be performed under one of the jars which are filled with water, the air will ascend as before; but instead of escaping, it will be detained in the upper part of the jar.

In this manner therefore, we see, that air may be emptied out of one vessel into another, by an inverted pouring, in which the air is made to ascend from the lower vessel *i* to the upper one *g*. This is owing to the pressure of the water on the air, or the lightness of the air, when compared with water. Thus a leaden bullet sunk to the bottom of a vessel of quicksilver will rise to the surface. The gas with which balloons are filled is lighter than common air, and therefore rises through it.

The reason why water will keep its place in the bottom of a vessel, is because it is heavier than air. Oil will rise through water, &c. When the receiver has a small neck, the air is poured through a funnel.

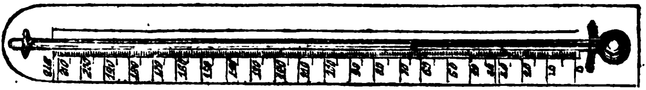

15

The *Differential Thermometer*, fig. 15, is designed to show the difference between the temperature of two places, at small distances apart. It consists of a glass tube of fine bore terminated at each end with a bulb, and bent into the form of the letter U. Sometimes it is made with one side longer than the other, as in the figure, and perhaps this is the most convenient construction. The tube is partly filled with some coloured fluid, as sulphuric acid tinged with carmine, or alcohol tinged with cochineal. The bulbs and a part of the tubes are filled with air.

It will be obvious from the construction, that this instrument cannot indicate the temperature of the atmosphere, or of a room as the common thermometer does; since an equal expansion of the air in both the bulbs would press equally on the fluid in both the tubes, and consequently it would rise in neither. But if one of the bulbs is exposed to a higher temperature than the other, then the expansion of the air in this, would be greater than in the other, and consequently the fluid would rise towards the bulb where the air was least expanded.

The use of the instrument, then, consists in showing the *difference* of temperature to which the two bulbs are exposed, as in experiments on the radiation of heat, hereafter described. The scale affixed to one of the legs, shows the rise of the fluid in degrees. The legs of the instrument may be from two, to four, or five inches high, and the bulbs an inch or a little less, in diameter. The stand to which it is fastened, may be of glass, or wood.

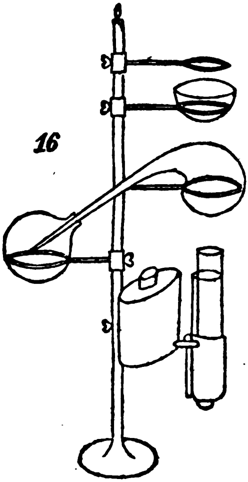
FARENHEIT'S THERMOMETER.



***Boiling point of Water*, 212.** ***Freezing point of Water*, 32.**

This is used to ascertain the actual temperature of the surrounding atmosphere, or of fluids. It consists of a hollow tube of glass, hermetically sealed, and at one end blown into a globe. This is filled with mercury, which also fills a part of the tube. The mercury expands with an increase of temperature, and again contracts with its decrease.

If, therefore, its bulb be plunged into hot water, the mercury rises in the tube ; if it be plunged into cold water, it sinks, and thus indicates the difference of temperature between the two bodies. The scale to which the tube is affixed, shews the degrees of heat from zero, 32 deg. below the freezing point, to 212 deg. the boiling point.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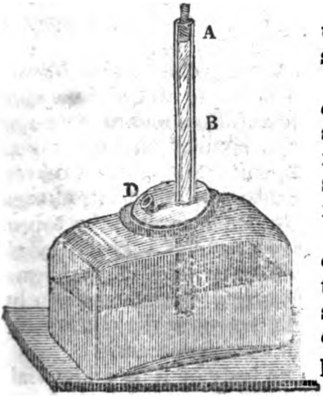
A *Lamp furnace*, fig. 16, consists of a brass, or iron rod, screwed to a foot of the same metal, or to a piece of plank loaded with lead On this rod slide three or four brass sockets, into which are screwed strait arms, terminated with brass or iron rings, of different diameters. The screws cut on the ends of these arms, where they go into the sockets are all of the same size, so that the rings may be changed from one socket to the other. These rings serve for supporting glass alembics, retorts, Florence flasks, gas bottles, &c. for performing distillations, digestion, evaporation, &c. By means of a thumb screw, passing through one side of each of the sockets, and acting on the rod, the rings may each of them, be set at different heights, or turned aside, according to the pleasure of the operator. The length of the rod is about three feet, and the diameter of the largest ring about four inches. The lamp is also fixed to a socket, so that the heat can be regulated by sliding it up or down.



Description of the *Aphlogistic or Flameless Lamp*. In the construction of this Lamp, the object is to keep a coil of wire in a state of ignition, without either flame or smoke.

The principle on which it is constructed involves two conditions, which are absolutely requisite, viz. that we make use of a combustible substance which evaporates at a low degree of heat, and a metal which is a bad conductor of caloric. For the combustible, alcohol seems best suited to this purpose. *Sulphuric ether*, aside from its high price, and disagreeable smell, I have sometimes found to fail; the ignition ceasing without any obvious cause.

In regard to the metal, gold and silver, both fail in consequence of the rapidity with which they conduct caloric. Silver, too, would soon be destroyed by the intense heat. Iron, although so bad a conductor, as to remain ignited for a time, soon fails, being converted into red oxide. Platina seems to be the only metal adapted to our purpose, being a slow conductor of caloric, and not easily oxidated at the highest temperatures.

This is to be drawn into wire of 56-100 or 60-100 of an inch in diameter, being about the size of card, or brass wire, No. 26. Experience has shown that this size succeeds better than any other. If larger the heat is carried off too fast, and the ignition ceases. If much finer, it does not retain sufficient heat at the lower part of the coil to keep up the evaporation of the alcohol from the wick.

The coiling of the wire, and the adjustment of the wick, are the most difficult parts of the construction.

The coil A. is made by winding the wire round a piece of wood, cut of the proper size, and shape. The size is to be determined by the bore of the glass tube, allowing for the diameter of the wire. The shape is plane cylindrical in that part which enters the tube, as seen in the figure.

The diameter of the coil is about one-sixth of an inch where it enters the tube. Its length half an inch, or a little less, containing from twenty to thirty turns of the wire. The projection above the tube is about one half of the length.

B. Is a glass tube, containing a cotton wick, which by capillary attraction carries the alcohol up to the platina coil. The length of this is is arbitrary, being from one to three or four inches. The bore is about the sixth of an inch, so as barely to admit the coil. The wick, consisting of eight or ten threads, is first drawn through the tube, and then introduced about half way into the coil, so as to come even with the top of the tube. This requires very nice adjustment. If the wick is too high, the wire is rapidly cooled by the alcohol, and ignition ceases in a few moments. If too low, the evaporation by the heat of the wire is insufficient. If, however, the other parts are well constructed, a few trials will ensure success.

C. Shows the lamp complete. The body of it is a low vial, or inkstand, capable of holding about two ounces of alcohol. It is stopped accurately with a cork, which is covered, for ornament, with tin foil. The aperture for admitting the tube and wick is made with a hot iron.

D. Is a small tube through which the alcohol is poured. A *dropping* tube is convenient for this purpose, but a small funnel is easily made by cuting off an inch of the neck of a broken retort, into which is pushed a cork, and through this a small quill.

When the lamp is completed and charged, the alcohol is inflamed by holding the coil in the blaze of a candle. After letting it burn for a few minutes; the flame is blown out, when, if every thing is properly adjusted, the wire will continue red hot until the alcohol is exhausted.

This lamp, though one of the most curious inventions of the age, is not merely a curiosity. The facillity and certainty with which, by means of a match, a light may be obtained from it, constitutes its utility. The proper matches for this purpose are prepared by dipping the common brimstone matches into a paste made by mixing two parts of white sugar with one part of chlorate (oxymuriat) of potash. The red French matches are of this kind, and answer the purpose completely.

In cases where a light might be wanted, but a constant one would be offensive, this lamp might be a great convenienc; a light being immediately obtained by merely touching a match to the platina coil, and then to the wick of a candle. Physicians or others who are liable to be called up in the night would also find it convenient.

LUTES.

Any substance made use of for closing the junctures of chemical vessels, is called a lute.

When the substance distilled has no corrosive property, a piece of bladder, cloth, or paper, spread with plain paste may be used. For corrosive substances, the fat lute, made of pipe clay and linseed oil, or common putty is used.

Where a coating for a glass vessel is required, common clay or loam, mixed with sand, and a quantity of cut tow, well beat together with a small quantity of water answers well. For a stopping between retorts and receivers, a strip of cloth wet with water and wound around the neck of the retort in some cases is sufficient. Where there is no heat, bees-wax softened and spread on cloth, makes one of the best lutes.

FORMS OF MATTER.

4. There are three general forms under which all known bodies exist: viz. under the form of solids, liquors, or of elastic fluids.

Def. Solids are such bodies as resist the impulses of other bodies. In solids the attractive forces of the particles predominate over the repulsive power of caloric. Their particles cohere so as to preserve them in masses, which have length, breadth, and thickness. Their hardness depends on the force of cohesion among their particles; hence some solids are much harder than others.

5. Almost all known solids can be converted into liquids, and many of them into elastic fluids, by being submitted to high temperatures.

Illus. The heat produced by professor Hare's *compound blowpipe,* is so intense as to fuse with one or two exceptions, every substance submitted to its power. Several substances formerly considered as infusable, are by this means converted into vapour.

Def. Liquids are bodies possessing considerable density, without the power, in an unconfined state, of resisting external impressions.

6. In liquids the attractive and repulsive forces may be considered as equal, and therefore their particles, although so near each other as to give them considerable specific gravity, are still so far apart as to permit them to move among each other on slight impressions.

Obs. Most of the known fluids become solids by the abstraction of caloric, or what is the same thing, by exposure to intense cold.

Illus. Mercury becomes a solid, malleable metal at 40 degrees below the zero of Farenheit. Ether becomes solid, and shoots into crystals at a certain degree of cold, and alcohol is said to have been frozen, &c.

Def. Elastic, or aeriform fluids, are such substances, as possessing little specific gravity, may easily be compressed into lesser bulks, but regain their former dimensions whenever the pressure is removed.

7. The permanent elasticity of aeriform fluids is owing to the repulsive power of caloric, with which their bases are chemically united, and which constitutes a part of their composition. In these substances, the repulsive, predominates over the attractive forces of their particles, as the attractive does over the repulsive forces of solids.

Obs. 1. It follows from the above considerations that *solidity*, *fluidity*, and *gasiety*, are only different *states*, of substances, and that they may be changed from one to the other without any change of composition. It is true that no degree of pressure, or cold has ever been known to condense the particles of an aeriform body, so that their attractive forces should overcome those of repulsion. But we know that by mechanical approximation of these particles an immense evolution of heat is produced, which is a convincing proof that their gaseous state is dependent on that repulsive power.

2. We already possess the means of converting nearly every known solid into the liquid state, and with perhaps, a single exception, every known liquid into the solid state. It is most probable then, that were our earth removed to a certain distance from the sun, all liquids, together with our atmosphere itself, would become a solid body, and were it to approach the sun, that the solids of which it is composed would be reduced to thin and invisible air.

◆

OF SIMPLE SUBSTANCES.

8. By simple, elementary, or primary substances, is meant all such as have not been decomposed, or separated into simpler forms of matter, and which no phenomenon, hitherto observed indicate to be compounds.

Obs. It is probable that many, if not all the substances, which in the present state of knowledge, are considered as simple, will ultimately prove to be compounds; there are already strong grounds for believing that some of them are so; but chemical writers have agreed that every substance which has not been actually decomposed should be considered as simple, whatever reasons there might be for believing it otherwise.

9. The number of substances considered as simple, amount to nearly sixty. Among these are *heat*, *light*,* *electricity* and *magnetism*. These are called *imponderable agents*. The others which amount to fifty-three in number, can be subjected to weight and measure, and are called *ponderable bodies*.

The ponderable bodies admit of the following classifications and divisions.

CLASS I.

Substances capable of uniting with metallic, or combustible bodies, and of either forming *oxides*, or effecting their combustion.

Oxygen,
Chlorine,
Iodine.

CLASS II.

Substances capable of uniting with oxygen, and forming with it *various compounds*.

DIVISION I.

Gaseous bodies.
Hydrogen, forming water,
Nitrogen, forming nitric acid.

DIVISION II.

Fixed infusable bodies.
Carbon, forming carbonic acid.
Boron, forming boracic acid.

DIVISION III.

Fusible, and volatile solids.
Phosphorus, forming phosphoric acid.
Sulphur, forming sulphuric acid.

CLASS III.

Metalic bodies capable of uniting with oxygen and of forming *oxides*, *alkalies*, *earths*, or *acids*.

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* In another place the pupil will find directions for *decomposing* the rays of light. This refers merely to the separation of its colours by the prism. In a *chemical* sense, this is not decomposition, since neither new combinations are formed, nor new substances obtained.

DIVISION I.

Comprehending such metallic bodies as are capable of forming by their union with oxygen, oxides, earths, or alkalies.

SUBDIVISION I.

Metals forming with oxygen, *ordinary metallic oxides*.

Gold,
Platina,
Silver,
Copper,
Iron,
Bismuth,
Lead,
Cadmium,
Nickel,
Tin,
Zinc,
Rhodium,
Palladium,
Manganese,
Cobalt,
Cerium,
Osmium,
Titanium,
Wodanium,
Uranium,
Tellurium,
Iridium.

SUBDIVISION II.

Metallic bodies forming *earths* with oxygen.

Calcicum, forming lime,	Earthly bodies with metallic bases.
Barium, forming barytes,	
Strontium, forming strontites,	
Magnium, forming magnesia,	Earthly bodies of doubtful characters.
Silicium, forming silex,	
Aluminum, forming alumine,	
Ittrium, forming ittria,	
Glucinum, forming glucina,	
Zirconium, forming zirconia,	
Thorinum, forming thorina,	

SUBDIVISION III.

Metallic bodies forming *alkalies* with oxygen.

Potassium, forming potash.
Sodium, forming soda.
Lithium, forming lithia.
Ammonium, forming ammonia.

DIVISION II.

Comprehending metallic bodies capable of forming *acids* by their union with oxygen.

Tungsten, forming tungstentic acid.
Arsenic, forming arsenic acid.
Chromium, forming chromic acid.
Columbium, forming columbic acid.
Antimony, forming antimonic acid.
Selenium, forming selenic acid.
Molybdenum, forming molybdic acid.

Obs. This catalogue contains all the substances which at the present day are considered as primary, or simple ; and they are arranged here merely as such. The first and second classes, and the first subdivision of the third class may be considered, in the present state of knowledge, as an exhibition of facts. The second subdivision of the third class is chiefly composed of articles of doubtful, or even of conjectural characters, their claims to be ranked as metals, being chiefly from their analogy to substance of known metallic bases. Among the number, lime, barytes, and strontites only, have exhibited direct proofs of their metallic bases. The others, as being earths, also, and as having most of them exhibited some signs of a metallic nature, have on these accounts been arranged by late writers on chemistry with the metals. Of the three articles under the third subdivision, of the third class, two of them *sodium potassium* have been known and recognized as metallic bodies for a series of years. Lithium is of more recent discovery, and as a metal has not been exhibited in a state of purity.

IMPONDERABLE AGENTS.

10. The imponderable agents are heat, light, electricity and magnetism. They are so called to distinguish them from substances which have appreciable weight.

OF HEAT OR CALORIC.

11. *Heat* is the sensation which one feels on touching a body hotter than the hand. This sensation is caused by the passage of *caloric* from the hotter body to the colder. Thus caloric, is the cause of the sensation called heat, and heat is the effect of the passage of caloric, or the *matter of heat*, into the hand,

Obs. One of the most obvious and universal properties of heat, is its disposition to seek an equilibrium, or to pass from the hotter body to that which is colder.

Illus. 1. If two bodies of different temperatures be placed in contact, or near each other, the one whose temperature is the highest constantly throws off heat from its surface, which is absorbed by the other, until the colder body has gained, and the hotter body has lost, a quantity of caloric, which bring them both to the same temperatures.

2. If two thermometers graduated exactly alike be placed at a distance from each other in the

open air, they will both indicate the same degrees of heat.

Corollary. Caloric has the power of pervading all substances, and of equalising their temperatures.

12. Caloric may exist in two different states, viz. in a state of *freedom*, and in a state of *combination*. In the former state it is capable of exciting the sensation of heat, and of enlarging the dimensions of bodies. In the latter state it neither excites sensation, nor produces obvious effects on substances.

13. Whenever we experience the sensation of heat, on touching a hot body with the hand, that body contains caloric in a state of *freedom*, otherwise it could not pass into the hand.

Obs. What in common language is meant by heat, is always free heat, since its other modification neither excites sensation nor affects the temperature of bodies. Thus a red hot ball of iron contains a large quantity of free heat.

14. Combined caloric, also called *latent* heat, neither affects sensation, the magnitude of bodies, nor the thermometer. A knowledge of its existence therefore is acquired by experiments only.

Obs. *Combined* caloric becomes *free* under circumstances to be mentioned hereafter.

OF FREE OR UNCOMBINED CALORIC.

15. Caloric, as a chemical agent, may be considered in two relations, viz. as the opposing power to cohesion, and as causing or increasing the elasticity of bodies.

16. As the antagonist to the cohesive attraction, or that power which keeps matter in masses, the effects of caloric, are to cause the particles of solids to repel each other, so as to overcome their natural attractions. When this takes place the particles easily slide over each other, and the sol-

id becomes a fluid, as in the fusion of metals, melting of ore, &c.

Obs. As the caloric passes out of a fused substance as a metal, the particles gradually approach, so as to regain the sphere of mutual attraction. Thus from a fluid, the metal, as it cools becomes a semifluid, or soft solid, and when the repulsive power of the heat is so weakened, by its loss, that it is completely overcome by the attraction of the particles, then the metal becomes solid as before. The forging of iron depends on this principle ; its particles being so far separated by the heat, as to move among themselves by the blow of the hammer.

17. As causing, or increasing the elasticity of bodies, caloric *combines* with the particles of some substances, so as not only to destroy their cohesion, but so as to throw them completely beyond the sphere of each other's attraction.

Illus. In all the permanently elastic fluids, as the atmosphere, and the gases, the substances of which these bodies are in part composed, are united to, or dissolved in, such proportions of caloric as completely to prevent their particles from coming within the sphere of mutual attraction. On this circumstance their permanent elasticity depends ; nor has the most powerful compression to which they have ever been submitted, brought their particles near enough to each other to feel the attractive influence.

On the contrary, the particles of those substances repel each other at indefinite distances. Thus the receiver of an air pump may be considered as full of air if it contains the least quantity, because as a part is removed, what remains instantly expands and fills its place, and this takes place until a perfect vacuum is formed.

It is on this principle that a celebrated writer has calculated, that if the pressure of the atmosphere could be removed, a cubit foot of air on the surface of the earth, would fill all the space between us and the fixed stars.

OF THE EXPANSIVE POWER OF CALORIC.

18. In general, all bodies are expanded by an increase of temperature, and contracted by its diminution. The ratio of expansion, however, differs greatly in different substances. Thus liquids

expand by the same degrees of heat much more than solids, and aeriform bodies most of all. There is a difference also in the same class of substances. Thus by the same increase of heat, one solid, or one fluid expands more than another.

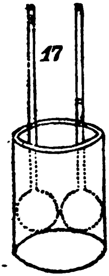
Illus. On making experiments on the expansibility of all the malleable metals, and many of their alloys, it has been ascertained that no two of them expand equally, when submitted to equal increments of heat.

Exp. 1. Fit to a bar of iron or large iron wire, a ring of metal so that the bar will just pass through it when cold. Then heat one end of the bar, or wire, and it will not pass through the ring.

2. Enlarge the ring, so that the iron will pass it when red hot. Then take a bar of copper of the exact size of the iron when cold; heat this red hot and it will be found too large to pass the ring.

Corol. The metals are expanded by heat, but some of them more than others.

19. The same increase of heat expands some liquids more than others.

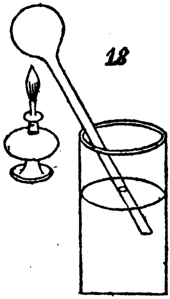


Exp. Take two glass tubes terminated at one end by large bulbs; fig. 17, fix a mark about half way up the tubes, and at the same height on each; fill one of them up to the mark with water, and the other with alcohol; Then place the bulbs of both in the same vessel of boiling hot water. Both of the fluids expand and rise up in the tubes, but the alcohol rises about twice as high above the mark as the water.

20. The expansibility of aeriform bodies of different kinds, is in the same ratio, at equal increments of caloric.

Obs. The degree of expansion which a body of this kind undergoes, is equal to 1-483 parts of its bulk for each degree of Fahrenheit, between the freezing and the boiling points.

Exp. 1. The expansion of air may be shown by partly filling a bladder by blowing into it; then tying the mouth so that none of it can escape, and holding it near the fire. The bladder soon becomes distended, and may be burst with an explosion by continuing the heat.



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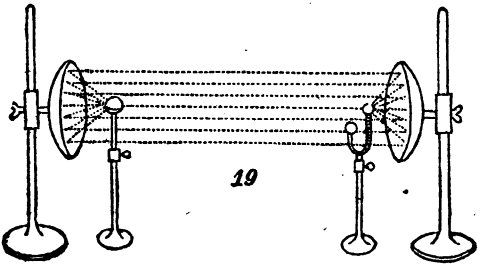
2. A more elegant experiment is, to take a glass tube terminated by a bulb, and fill the tube about half way with water. Then immerse the end of the tube in a vessel of water, fig. 18, and apply heat to the bulb. As the heat rarifies the air, the water will be seen to descend in the tube.

21. When we approach an ignited body, we become sensible that it emits caloric without touching it; and if a thermometer be carried near it, this indicates an increase of temperature.

Obs. The caloric thus imparted is called *radiant* caloric. It is not *conducted*, but passes through space independently of other matter with amazing velocity. Thus the sun radiates his heat to the earth at the rate of two hundred thousand miles in a second.

22. Radiant caloric, like light, is reflected by polished surfaces, and in respect to the angles of incidence, and reflection, it follows the same laws.



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Exp. Provide two circular concave tin mirrors, fig. 19, of about 10 or 12 inches in diameter, and two inches deep. They are made by planishing the tin with a round faced polished hammer, and afterwards made as bright as possible by rubbing with buckskin and whiting. They may be supported in the perpendicular position by having slips of tin soldered on their backs, and then fastened to wooden stands.

Place the mirrors, being both of the same height, on a table opposite to each other, and about 10 or 12 feet apart. Place a screen, made of paper or board, between them. In the focus of one mirror set the bulb of an air thermometer, or what is better, the differential thermometer, and in the focus of the other a cannon ball heated below redness. When every thing is ready, remove the screen, and the thermometer will immediately indicate an increase of temperature.

By having the ball red hot, and placing the mirrors nearer each other, and substituting gunpowder for the thermometer, a very striking experiment may be witnessed. When every thing is prepared in this way, remove the screen, and the powder flashes.

Obs. In these experiments the caloric flows first from the hot ball to the nearest mirror, which reflects it in parallel rays to the other mirror, by which they are again reflected, and concentrated upon whatever is placed in its focus.

23. The surfaces which are best adapted to the reflection of caloric, do not reflect light equally well.

Exp. On holding before a blazing fire, a *glass* mirror, it reflects most of the light, while the heat is reflected in a very small proportion, and the mirror soon becomes hot. On the contrary, if a *metallic* mirror be substituted in place of the glass, it will reflect a great proportion of the heat, but less of the light, and will remain cold.

24. The nature, or colour, of the surface of bodies has an important influence over their power of radiating caloric.

Illus. The rate at which bodies cool, so far as their surfaces are concerned, seems to be in an inverse ratio to their polish, or brightness. Thus metallic vessels with polished surfaces retain heat longest; if they are tarnished by handling, or if the polish be destroyed, or if they are painted, the rate of cooling is increased; and this in direct proportion as the surface varies from a polish, or approaches towards a black colour.

Exp. Take a cannister of tin forming a cube of about six inches. Let a spout be made on one side for pouring in water. Paint one side of the cube black; destroy the polish of another side with sand paper; tarnish the third by rubbing on quicksilver, and leave the fourth bright. Then fill the vessel with boiling water and set it in the focus of one of the mirrors and the air thermometer in the other, as in the experiment to prove the radiation of caloric; When the bright side is turned towards the nearest mirror, the thermometer in the focus of the other, is scarcely affected; when the tarnished side is turned towards it, the thermometer shows that the radiation is increased, when the black side is turned towards it, the fluid rises rapidly. The difference between the bright and black sides are so great as to be perceptible to the hand.

CONDUCTORS OF CALORIC.

25. Solid bodies conduct caloric in all directions; upwards, downwards, and laterally.

Exp. Hold a rod of iron obliquely over a lamp or furnace, and it will be heated both above and below the fire.

26. Some bodies conduct caloric much more rapidly than others.

Exp. Coat with wax the ends of two rods of the same size, and length, one of glass and the other of iron, or any other metal; then place the uncoated ends in a vessel of boiling water. The wax on the metallic rod will be melted, while that on the glass remains cold.

27. Liquids, and elastic fluids, do not *conduct* caloric, but *convey* it by changing the places of their particles.

Illus. That portion of the fluid which is nearest the source of heat, is expanded, and rises up, carrying with it a quantity of caloric, while that portion which is colder descends, and in its turn, is heated and rises, while another portion descends, and thus the process goes on as long as the fluid is capable of imbibing heat.

Exp. 1. Take a tall glass jar, or vial, and nearly fill it with cold water, and put into the water some particles of amber, or any other substance about the specific gravity of water; then immerse the jar in a vessel of boiling water. The motion of the particles of amber will show two currents in the jar, one upwards, along the sides where the heat is greatest, and one downward, in the centre.

2. Take a glass tube, 10 or 12 inches long, closed at one end, and put into it an inch or two of coloured water, and then fill the tube by carefully pouring in common water by means of a dropping, so as to keep the two strata quite distinct. If now the upper end of the tube be heated, the water may be made to boil at this part, while the two strata at the bottom remain un-

disturbed. But if the tube be afterwards heated at the bottom, the coloured fluid will rise up and tinge that above it.

OF COMBINED, OR LATENT CALORIC.

28. When a solid is converted into a fluid, or a fluid into the aeriform state, a quantity of caloric is absorbed, which is not appreciable by the thermometer, nor sensible to the touch. This is called *combined* or *latent* caloric.

Obs. The quantity of caloric absorbed by melting ice, is much more than can be accounted for by the corresponding difference between the temperatures of the ice and the water, as indicated by the thermometer, or by sensation. A quantity of caloric, then, is absorbed by the melting ice; combines with the water, and forms a part of it. Thus water is a compound of ice and caloric. But the caloric is so confined by its intimate union with the water, as not to be given out during its liquid state, and consequently it cannot excite sensation. The following experiment will illustrate this fact.

Exp. Expose a pound of water at 32 deg. and a pound of ice at 32 deg. in a room the temperature of which is 60 deg. and uniformly the same during the experiment. Place the bulb of one thermometer in the vessel of water, and another in that containing the ice. The thermometer in the vessel of water will very soon begin to rise, and will gradually reach the temperature of 60 deg. while that placed in the ice will steadily continue at 32 deg. for several hours, or until the ice is entirely converted to water; it will then begin to rise, and from this time it will take just the same number of minutes, for the water in this vessel to reach the temperature of the room, as it did in that at the beginning of the experiment.

Obs. Although during this experiment the ice remained at 32 deg. yet it must the whole time have been absorbing caloric, because a colder body cannot be in contact with a warmer one, without receiving caloric from it. The caloric, therefore, which turned the ice into a liquid, or caused its fluidity remains fixed, or latent in the water.

Corol. The fluidity of water is owing to a quantity of caloric which it contains in a latent state.

29. During the conversion of liquids into steam or vapor, caloric is absorbed.

Exp. Moisten the bulb of a thermometer with ether, and expose it to the air. The mercury will sink, and by repeating it, especially if the evaporation be increased by an air pump, it will sink down to the freezing point in warm weather.

Corol. Ether requires caloric to convert it into vapor; a part of which it absorbs from the bulb of the thermometer.

Obs. In all cases of evaporation caloric is absorbed.

30. Steam contains a large quantity of caloric, in a latent state.

Exp. Let a pound of water at 212 degrees, and eight pounds of iron filing at 300 degrees be suddenly mixed together, a large quantity of steam will be instantly generated; but the temperature of the mixture will be only 212 degrees, nor will the temperature of the steam be higher than this.

Corol. The steam therefore must have contained in a latent state all the caloric which the eight pounds of iron contained over 212 degrees, since neither the mixture nor the steam was of a higher temperature than this.

Obs. From the experiments of Dr. Black, and others it has been calculated, that steam contains near 1000 degrees of heat in a latent state, and consequently over, and above what is indicated by the thermometer.

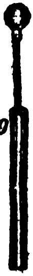
31. When liquids, or elastic fluids pass from a rarer, to a denser state, caloric is evolved.

Illus. When water freezes it gives out caloric which kept it in the fluid state, otherwise it cannot become a solid. Dr. Black has long since calculated that ice, in becoming fluid, absorbs 140 degrees of caloric which remains latent in the water; this quantity of caloric must therefore be evolved, independently of what the thermometer indicates, before the liquid can become a solid.

Obs. 1, That the water gives out heat when it freezes is shown by the following experiment.

Exp. Put some water into a thin glass vessel, and surround it with a freezing mixture, or expose it to intense cold in winter, (the vessel having a small thermometer in it,) keep the vessel perfectly still, and the thermometer will sink several degrees below the freezing point; if now the vessel be shaken, the thermometer will rise up to 32 degrees, and the water freezes. Many other experiments show that the water gives out heat as it becomes solid.

The evolution of caloric by the condensation of an elastic fluid is shown as follows.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Exp. Take a metallic tube, fig. 20, stopped at one end, and five or six inches long, the bore being less than half an inch wide. Fit it to a piston and handle, the piston being air tight. Have the lower end of the piston excavated so as to put in a little tinder.

If the piston be forced quickly down nearly to the bottom, the compression of the air produces so much heat as to set fire to the tinder. In this way a fire may be readily kindled.

OF SPECIFIC HEAT.

32. Equal weights of the *same* substance at the same temperature, contains the same quantities of caloric. But equal weights of different substances at the same temperature contain unequal quantities of caloric. The quantity of caloric which one body contains, when compared with what another contains is called *specific caloric.* When one body of equal weight contains more than another, that body which contains the most is said to have a greater *capacity for caloric* than the other.

Obs. We should suppose, did not experiment teach the contrary, that equal weights of matter, of whatever kind placed in the same room, and under the same circumstances, would contain the same quantities of heat. This however proves not to be the case.

Exp. 1. Mix a pint of water at 100 degrees, with another pint at 40 degrees, and the temperature of the mixture will not vary much from 70 degrees,* which is the arithmetical mean.

Corol. Equal weights of the same substance at the same temperature contain equal quantities of caloric.

Exp. 2. Mix a pint of quicksilver at 100 degrees, with a pint of water at 40 degrees, and the resulting temperature will not be 70 degrees, as in the last experiment, but only 60 degrees.

Obs. However unexpected the result might be, this experiment proves that a pint of quicksilver, although it weighs about fifteen times as much as the same bulk of water, does not contain so much caloric. In the other experiment one pint of water at 100 degrees raised the temperature of another pint at 40 degrees up to 70 degrees, but here a pint of quicksilver at the same temperature raises the heat of the same quantity of water to only 60 degrees. The quicksilver looses 40 degrees, being 100 degrees when the experiment began, which nevertheless raises the temperature of the water 20 degrees. This shows that it takes a greater quantity of caloric to raise the temperature of water through a given number of degrees than it does the same bulk of quicksilver.

Obs. 2. If, instead of equal *bulks* of the water and mercury, we take equal *weights* the disparity will be still greater.

Exp. 3. Mix a pound of water at 100 degrees with a pound of mercury at 40 degrees, and the heat of the mixture will be 97 1-2 degrees, that is 27 1-2 above the arithmetical mean; because when equal weights of water were mixed, the temperature was only 70 degrees. Here then the water has lost only 2 1-2 degrees, while the same weight of mercury has gained 57 1-2, the temperature of the mercury being only 40 degrees when they were mixed, while that of the water was 100 degrees.

Corol. The inference to be drawn from these experiments is, that water has a much greater capacity for caloric than mercury has; because, by the first experiment equal weights of the same fluid at different temperatures produced an arithmetical mean; but when the mercury is used instead of water, the temperature of the mixture is much higher than the arithmetical mean, therefore the water communicates more caloric to the mercury, than this does to the water, so that at the same temperature, water contains more caloric than mercury; in other words, it actually takes more caloric to raise the heat of water a degree, than it does the same quantity of mercury a degree, therefore the caloric which enters the water to raise it a degree, over and above what would have raised the mercury a degree, is contained in the water, and is given out again when the water cools.

OF THE SOURCES OF CALORIC.

33. The sources of caloric may be reduced to six, viz. the *sun*, *combustion*, *percussion*, *friction*, *mixture*, and *electricity*.

The *sun* constantly radiates caloric to the earth, and is the great fountain of heat to us, and the whole solar system.

35. *Combustion.* This supplies the heat made use of in the arts, and for culinary purposes. It is given out by the oxygen of the atmosphere, as it unites with the burning body, and supports its combustion.

36. *Percussion.* It is well known that heat is produced by the percussion of hard bodies against each other. The evolution of caloric is owing to the temporary, or permanent condensation of the body struck, in consequence of which, the latent heat becomes free, or sensible heat, as already explained in respect to fluids.

Exp 1. Take a piece of soft iron, and strike it smartly several times with a hammer on an anvil. The iron becomes hot, and even red hot, if the experiment be well conducted.

Corol. The latent heat is forced out of the iron in consequence of the condensation produced by the blows of the hammer.

Exp. 2. Strike a piece of hardened steel and a piece of flint smartly together. Sparks of fire will be produced.

Corol. The condensation produced by the percussion, forces out so much heat as to inflame the small particles of steel that are struck off.

37. *Friction.* Caloric is evolved, or produced by friction.

Illus. The friction of machinery, where the motion is rapid, frequently causes so much heat as to set wood on fire.

Fires may be kindled by rubbing pieces of dry wood smartly together.

The wheels of carriages, by turning rapidly on their axletrees, sometimes evolve so much heat as to set them on fire.

Obs. The principle on which caloric is produced by friction is not demonstrated. It cannot be referred to condensation, because the rubbing of two soft bodies together produces heat, when it cannot be supposed that their densities are increased, as on rubbing the hand on the coat sleeve, or on rubbing the hands together. Count Rumford, who made a laborious, and varied set of experiments on this subject, was led to conclude that the heat produced by friction, could not be connected with the decomposition of oxygen gas, nor with the increase of density, nor could it be owing to any alteration in what is called the specific caloric of bodies. Others have also made experiments with a view to determine this question, but as yet no one has pretended to give any satisfactory explanation of it.

38. *Mixture.* In a great number of cases, when two substances are mixed together, and enter into a chemical union, heat is evolved. This phenomenon is explained partly on the principle of increased density, and partly on the supposition, that the two substances, owing to a different arrangement of their particles, have not the same capacity for latent heat when combined, as they had in a separate state.

Exp. 1. Sprinkle water on unslacked quicklime. A temperature of 800 degrees may be produced in this way.

Obs. In this case one of the articles undergoes a great increase of density. The lime absorbs in slacking, a large quantity of water, which it retains, and which forms a part of its substance. The caloric, therefore, which is evolved by this experiment, is easily accounted for by the general law, that heat is given out whenever a substance passes from a rarer to a denser state. Here a fluid is converted into a solid.

Exp. 2. In a thin glass vessel, mix at once four parts of sulphuric acid and one part of water. A heat much above that of boiling water will be produced.

Obs. On measuring the two fluids before they are mixed, and afterwards, it will be found that they have lost a part of their bulk by mixture. This is probably owing to the new arrangement which the particles of one, or both of the fluids take, when they combine with each other, so that the evolution of caloric, may be accounted for on the same principle as in the last experiment. It is probable, also, that in both of these cases, there is a loss of capacity for caloric in one or both the substances.

39. *Electricity.* Whenever two bodies in different electrical states are brought near each other, so as to produce a discharge of electric fluid through air, there is a flash of light attended with heat.

Obs. The cause of this heat, according to the theory of Sir Humphrey Davy, (who considers the two electrical states as two distinct fluids) is the union of the two electricities, the positive and negative. These fluids, while separate, says the theorist, produce no phenomena, but when they unite they lose their electrical properties, and constitute heat.

It is well known that the heat produced by a large galvanic battery, is more powerful than has been produced by any other means.

LIGHT.

Obs. The properties of light, its laws of reflection and refraction, and its effects on the sense of vision, are subjects belonging to the science of *optics*. Chemistry, however, claims an examination of some of its effects, as being capable of producing chemical phenomena.

40. Light may be decomposed by means of a prism into seven *primary colours*. The heating powers of these different colours are different.

Exp. Take a sensible air thermometer, and move the bulb in succession through all the different coloured rays, waiting at each one for the fluid to rise or fall. The thermometer will be found to indicate the greatest heat in the red ray; next in the green, and so on in diminishing progression to the violet.

Obs. When the thermometer is removed entirely out of the red rays, but with its bulb still in the line of the spectrum, it rises higher than it does in the red rays. These heating rays are invisible, so that the prism has the power not only of separating the light into its primary colours, but also of separating the heat from the light.

41. The prismatic rays of light differ in their power of illuminating objects.

Illus. If an equal portion of each of these rays, one after the other, be made to illuminate a minute object, a printed page for instance, it will not be seen at the same distance, when illuminated by each.

42. Light is capable of being absorbed by bodies, of remaining in them for a time and afterwards of being extricated unaltered. Such bodies are called *solar phosphori*.

Obs. A great number of substances are known to have the power of absorbing light, when exposed to the sun, and of emitting it again when carried into the dark. Most substances lose this property in a very short time, probably in consequence of the emission of all the light they had absorbed, but they recover it again on exposure to the light, and this may be repeated any number of times. Some particular compositions, have the property of becoming so luminous in this way as to render minute objects visible in the dark. Canton's phosphorus is of this kind. It is prepared as follows.

Exp. Take common oyster shells, and calcine them in a coal fire for an hour, then select the whitest, and purest parts, which are to be pounded and sifted. Mix three parts of this powder, with one part of the flowers of sulphur, and press the mixture into a crucible, which must be kept red hot for one hour. Then let the crucible cool, and select out the brightest and purest parts, which cork up in a dry well stopped vial. When this composition is exposed for a few minutes to the light and then carried into the dark, it is sufficiently luminous to enable one to distinguish the hour by a watch.

Obs. 1. The same property is possessed by several other preparations, as Baldwin's and Homberg's phosphorus, in a similar degree. It seems also that the diamond has this property. Thus Du Fay, exposed one to the light and immediately covered it with black wax; at the end of several months, the diamond shone in the dark. Sheets of white paper, snow, white linen, and many other substances of this colour, absorb and emit light, in a greater or less degree.

2. The extrication of light is facilitated by exposing the solar phosphori to an elevated temperature. Thus after Canton's phosphorus has ceased to shine in the cold, it will emit light on being heated. Some substances, which do not otherwise give out light, evolve it, or become *phosphorescent* when heated. Fluate of lime is of this kind; if some of it, in powder, be thrown on a hot shovel, it shines in the dark. Several kinds of crystalized stones shine on being rubbed in the dark: tremolite, and some specimens of quartz are of this kind. Loaf sugar, when mixed with whites of eggs and dried, as is done for the frosting of cake, gives out much light on being scratched with a sharp point.

43. Light is emitted during chemical changes independent of heat, or in which no heat is perceptible.

Illus. Particular marine animals emit light both in the living and the dead states. As instances of the first, we notice the shell fish called *pholas*, also the *medusa phosphorea*, and others of the mollusca species. Marine fishes in general when deprived of life emit light. The flesh of quadrupeds, during decomposition, evolves a phosphorescent light. Among insects, are several species which have the power of emitting light, as the lanthorn-fly, glow-worm, &c. It is well known that rotten wood is sometimes so luminous as to enable one to tell the hour by a watch. In all the above instances, and a great variety of others might be mentioned, there is no perceptible heat.

44. Light seems to be a constituent chemical principle of some bodies, particularly of marine fishes, from which it may be separated, retained, and rendered for a while permanent.

Illus. When four drachms of whiting, herring, or mackerel, are put into a vial containing two ounces of sea water, or of pure water, holding in solution half a drachm of common salt, or two drachms of sulphate of magnesia, if the vial be put into a dark place, a luminous ring appears on the surface of the liquid within three days, and the whole liquid, if shaken, appears luminous, and continues in that state for some time.

45. Very sensible changes are produced in bodies by the absorption of light.

Illus. Plants may be made to vegetate in the dark ; but in that case their colour is always white, they have little taste, and contain but a very small proportion of combustible matter. On exposing such plants to the light, their colour becomes green, their taste becomes much more intense, and the quantity of combustible matter is much increased. These changes are very obvious, and they depend incontestibly upon the agency of light.

Another very remarkable instance of the agency of light is the reduction of the metallic oxides. If the red oxide of lead be exposed to the light, a part of the oxygen makes its escape ; this is also the case with red oxide of mercury. If a salt of silver, as lunar caustic, be exposed in the same way, it becomes black, and on examining it with a magnifying glass, the silver is found to be partly reduced to the metallic state.

46. Plants emit oxygen gas on exposure to light.

Exp. Fill a glass vessel, as a bell glass, with water, and invert it on the shelf of the water bath, or in a dish of water. Introduce under the vessel, and into the water, some sprigs of mint, or any other plant of vigorous growth ; then expose the vessel to the action of the sun. Bubbles of oxygen gas will be extricated from the leaves of the plant, and will rise to the upper part of the vessel.

Obs. This experiment might give the pupil reason to suppose that the presence of water was necessary to induce plants to give out oxygen, or that it was in some way concerned in its extrication. This however is not the case. The water is necessary, only because we cannot collect the gas without it. It is the *air* contained in the water, which the plant decomposes, and in consequence of which the gas is evolved.

Plants, during their growth, absorb carbonic acid gas which the air contains, and retain the carbon, which forms a part of their bulk, but give out the oxygen. In this experiment, then, the plant absorbs, and retains the carbon which the air in the water contains, and gives out the oxygen gas, which rises to the upper part of the vessel. If the experiment is made with boiled water, containing no air, the plant does not give out oxygen gas. See Vegetation.

47. Light has an important and curious influence on the crystalization of salts.

Exp. Into a darkened room, let in a ray of light, through a small aperture. Expose to this ray a small shallow dish containing a strong solution of the sulphate of iron in water, one half of the dish being covered with a black cloth so that this part will be completely darkened ; set the dish so that the light will strike only on the uncovered part. Let the dish stand in this situation for a day or two, so that the salt shall have time to shoot into crystals, or vegetate. On examining the solution at the end of this time, it will be found that the salt has not vegetated in that part which was covered from the light, but in the half only which was uncovered.

48. Light has the power of exploding a mixture of the two gasses, chlorine, and hydrogen. See *Chlorine.*

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OF AFFINITY.

49. By the best directed experiments, it has been demonstrated that all bodies, of which the material universe is composed, have a mutual tendency to approach each other, and to unite in a single mass. The force of this mutual inclination to unite, whether among the masses of matter or their particles, is called ATTRACTION : and it is this

force by which the planets are kept in their orbits, and the atoms of bodies are held together.

50. Attraction is mutual; it extends to indefinite distances. All bodies whatever, as well as the particles of which they are composed, are endued with it. It is not annihilated by space, but operates at the amazing distances at which the planets are placed from the sun, and probably between the solar system and the fixed stars.

51. The cause which produces this reciprocal attraction is altogether unknown to us, whether it be inherent in all matter, or whether it be the consequence of some other agent, are questions beyond the reach of human decision.

Obs. That the power of attraction really exists is obvious from the slightest view of the phenomena of nature.

Exp. 1. Place two globules of quicksilver on a piece of dry glass, or any other smooth surface, and push them slowly towards each other. When within a certain distance, depending on the size of the globules they will spontaneously run together and form one mass.

2. If two pieces of cork, or wood, be placed in a dish of water, near the centre, and at a short distance from each other, they will be seen to approach with a rapidity of motion according to the proportionate size of each.

Corol. These two experiments show that an attractive power exists between the masses of matter, and that the force of attraction is proportionate to their quantities.

3. If a small glass rod, or stick, be dipped into water, or any other fluid, and drawn out again, a drop will be found suspended at the end of it of a spherical, or round form.

Obs. The fact that all fluids take the globular form whenever their particles are permitted to arrange themselves according to the laws of cohesive attraction, is demonstrated by the most common occurrences. Thus when water is thrown on oil it forms itself into globules. When thrown into the air, so as to freeze, it comes down in this form. Shot are made by pouring melted lead from such a height as to permit the globules to cool before they reach the ground, &c.

Corol. The globular form which the drops of fluids assume, is owing to the mutual and equal attraction of their particles.

Thus every particle approaches the centre of the drop as nearly as possible. Hence no other figure could be formed, nor could this figure be formed by any other law.

52. The circumstances under which attraction takes place are various, and it consequently becomes necessary to denote the different phenomena which it occasions by distinct appellations.

53. *Attraction* of *gravitation* is that force by which masses of matter tend towards each other, as when a heavy body suspended in the air, constantly gravitates towards the earth, and if set free, will fall upon it.

54. *Affinity* of *aggregation* or *cohesive attraction*, is that force or power by which particles of matter *of the same kind* attract each other, and unite so as to form a mass.

Obs. This kind of attraction has nothing to do with the formation of compound substances, its effect being simply to keep the particles of bodies together, so as to form solids. Thus a lump of copper may be considered as composed of an infinite number of small particles *cohering* together.

55. Chemical affinity is that power which brings particles of different kinds to unite into a mass, and to form one compound whole.

Obs. 1. The difference between cohesive attraction and chemical affinity is easily recognized. Thus in the lump of copper, the particles are *homogeneous* and are kept together by the force of *cohesion*. But if the copper is dissolved in nitric acid, this cohering force is entirely overcome, and the particles of copper are separated and diffused in the liquid. If the solution is suffered to stand for a time, a new kind of attraction begins to operate. The particles of the metal and those of the acid combine and form a compound which has none of the properties of the acid, or the metal. This union is the effect of *chemical attraction*, or *affinity*.

2. It will be remembered that chemical affinity merely forces particles of different substances to combine.

56. Chemical affinity is of two kinds, viz: *Elective affinity*, and *complex*, or what is sometimes called

double elective affinity. It is also called *compound affinity.*

57. *Elective affinity* is that power, or quality in the particles of certain substances which forces them to unite with each other, in preference to uniting with those of a third. Thus A B and C being in solution together, the particles of A and C elect each other, and unite together, while B is excluded.

Obs. This is one of the most important laws in chemistry, and is the basis on which its theories as a science, and its practice as an art, are chiefly founded.

58. *Complex affinity* is a modification of elective affinity, and depends on the same law.

Obs. In elective affinity only three substances are supposed to be in solution; two of these unite and form a compound, while the third is rejected, and remains uncombined. In complex affinity there is supposed to be at least four ingredients dissolved, so that a double decomposition and interchange of particles can be effected.

Illus. If there be dissolved in one vessel some muriate of lime, and in another some sulphate of soda, when these two solutions are mixed, both these salts are decomposed and two new ones are formed, the lime quitting the muriatic acid, unites to the sulphuric acid and forms sulphate of lime, while the muriatic acid of the muriate of lime, and the soda of the sulphate of soda, being set at liberty, combine and form muriate of soda.

Remark. The kinds of affinity particularly belonging to chemistry, are the *cohesive*, *elective*, and *complex.*

59. *Cohesive affinity* is most strongly exerted in solid bodies. Its force is proportionate to the mechanical power required for effecting their disunion. In a chemical point of view, this force is to be considered as modifying or counteracting the force of affinity; for the more strongly the particles of any substance are united by this power, the less are they disposed to enter into combination with those of other bodies.

Obs. The cohesion of bodies may be overcome *by mechanical division*, by *heat*, and by *solution.*

Illus. The cohesion of some substances may be overcome by rasping, some by grinding, and others by pulverizing. In many substances, one or the other of these modes of breaking up the cohesive force, is requisite before they can be brought to enter into chemical union with other bodies.

In most cases that of pulverizing is employed, and the finer the levigation, the more easily and quickly does the substance enter into combination. Thus in the analysis of some of the ores, it is necessary to reduce them to an impalpable powder, before they can be dissolved in any acid, &c.

Exp. 1. Throw a lump of *fluor spar* into a vessel of sulphuric acid and the two substances will scarcely act upon each other at all; but if the spar be finely pulverized and then mingled with the acid, a violent action instantly takes place.

2. If common salt be thrown into water in lumps, it dissolves slowly, but if it is first reduced to a fine powder, it dissolves in a few minutes.

60. Cohesion may be counteracted by *heat* in almost every substance with which we are acquainted.

Obs. Heat is the great opposing power to cohesion, and is capable of overcoming it in every instance, provided its intensity be in proportion to the force of cohesion.

Illus. 1. The cohesive force of the particles of *quicksilver* is overcome at the ordinary temperature of the atmosphere, for when the metal is exposed to a very low temperature, and the repulsive power of caloric becomes weakened, the attractive force of its particles causes it to become a solid metal.

2. Tin melts, or the cohesion of its particles are destroyed, at about 450 degrees of heat. Copper fuses at 4587 degrees. Platina at 23,177, &c. It is plain then, that at proper degrees of heat, solids lose the cohesion of their particles and become fluids.

Corol. The cohesive attraction depends on temperature, and is entirely destroyed at certain degrees of heat proportionate to its strength.

61. *Solution* is the third mode of counteracting cohesion.

Def. The term *solution* is applied to a very extensive class of phenomena. When a solid disappears in a liquid, or when a solid or liquid is taken up by an aeriform body, if the compound exhibit perfect transparency, we have in each instance an example of *solution*.

Illus. When common salt is thrown into the water it disappears and we have a solution of salt in water. When the salt is added until the water can dissolve no more, the solution is said to be *saturated.*

2. During the process of evaporation at common temperatures, the water disappears by entering into solution with the air of the atmosphere. Thus air always contains a quantity of water in solution, which it deposits under certain circumstances.

Obs. 1. By evaporating the fluid, the salt may again be obtained, for as the particles of water leave those of the salt, the cohesive attraction again begins to operate, and solids are formed.

2. When two salts are contained in the same solution, which vary in their degrees of solubility, and which have no remarkable attractions for each other, they may be obtained separate. For by carefully reducing the quantity of the solvent by evaporation, the salt whose particles have the greatest cohesion will crystalize first. If both salts are more soluble in hot water than in cold, the crystals will not appear till the liquid cools. But if one of them, like common salt is equally soluble in hot and in cold water, crystals will appear, even during the act of evaporation. In this way we may completely separate nitre from common salt, the crystals of the latter being formed during evaporation; while those of the nitre do not appear till some time after the fluid has cooled.

63. CRYSTALIZATION, is that process by which the particles of substances unite together, and form solids of regular and determinate shapes.

Obs. As preparatory to this result, it is in all cases necessary that the substance to be crystalized should be in a state of solution, so that its particles may have free liberty to move among themselves, and to assume their places according to the law of affinity.

Illus. In ordinary cases the solvent is water, this being the proper menstruum for most of the salts. In other cases it is caloric, as several of the metals are capable of being obtained in regular crystals when dissolved in caloric, or melted. Sulphur may be crystalized in the same way.

64. In some cases the affinity of a salt for its solvent is so strong as not to permit it to separate in the form of crystals.

Illus. This is the case with potash when dissolved in water. But if potash is dissolved in a fluid for which it has a weak affinity, it is easily obtained in crystals. Thus a solution of this alkali in alcohol deposits regular crystals.

65. In general, all crystals composed of the same ingredients, appear under the same forms. In other words all the crystals of the same substance are alike in respect to their shapes, and the number and quantity of their angles, these being with certain exceptions, different from those of any other substance.

Illus. If common salt be dissolved, and slowly evaporated, it forms regular cubes. If it be dissolved again, it will form figures of exactly the same shape, and this will be the case as often as it is permitted to crystalize.

The crystals of nitre have the shape of a six-sided prism, those of alum are eight-sided, &c. In every instance the salt assumes its own peculiar figure, and with certain exceptions, every crystal of the same substance has the same number of angles, whose quantities when measured are found to be equal to each other respectively.

Obs. The determinate and invariable forms under which all the crystals of the same substance appear, is accounted for, on the supposition that the particles of each substance have a shape peculiar to themselves, and that during the process of crystalization they take the same position in respect to each other. In this case it is obvious that the same figure would be produced in every instance.

66. From an extensive examination of the forms which different substances assume when crystalized, together with their chemical analysis, it has been laid down as a general principle, that *identity of crystalline form is necessarily connected with identity of chemical composition.*

Obs. Were this principle universally, and without an exception true, its discovery would greatly abridge the labour of the chemist. For, by an inspection of the form of a crystal, its composition could be told without analysis, while the analysis of an imperfect or broken crystal would indicate the exact form of the perfect ones. It has however been ascertained, that although this rule holds good in general, it has failed in particular instances. Thus crystals have been found under the same form which differed greatly in composition, while those of the same composition have assumed different forms. These facts do not however destroy the general principle, which may still be considered as true.

67. By particular management the crystals of almost any salt may be made to assume a much larger size, and more beautiful appearance than is ordinary.

Illus. Dissolve the salt to be crystalized in water, for example, alum; concentrate the solution slowly by evaporation, to such a degree that it shall crystalize on cooling, which may be known by suffering a drop of it to cool on a plate of glass, or other substance. This being done, put the solution aside, and when perfectly cold pour off the liquid portion from the mass of crystals at the bottom, and put it into a flat-bottomed vessel.

After having stood for some days solitary, crystals will begin to form at some distance from each other, which gradually increase in size; select the most regular of these, and place them in a flat-bottomed vessel at some distance from each other, and pour over them a quantity of the concentrated liquid obtained by evaporating a solution of the alum, till it crystalizes on cooling. Alter the position of the crystal at least every day, with a glass rod, that all the faces may be alternately exposed to the action of the liquid: for the side on which the crystal rests, or is in contact with the vessel, never is increased. The crystal will thus gradually grow, or increase in size.

When they have grown to such a size that their forms can be easily distinguished, let the most perfect ones be selected, or those having the exact shape you wish to obtain, and put them separately in a vessel filled with a portion of the same liquid, and let them be turned in the manner directed several times a day. By this means they may be obtained of almost any size we wish.

When the crystal has continued in the liquid for a certain time, the quantity of alum held in solution becomes so much diminished, that the liquid begins to act upon the crystal, and redissolve it. This action is first perceptible on the angles and edges of the crystal: they become blunted, and gradually lose their shape. Whenever this begins to be perceived, pour off the liquid, and replace it by some newly prepared. The crystal may be made to grow in length by laying it on its sides, and in breadth by placing it on its base, or setting it up.

68. CHEMICAL AFFINITY, like cohesive attraction, is effective only at insensible distances.

Illus. If the particles of two substances, having affinity for each other, are kept at such a distance, as that we can by any means observe space between them, the force of attraction does not operate. In this respect chemical affinity differs greatly from attraction of gravitation, which operates at indefinite distances. They differ in this also, that the first affect particles only, while the other operates on masses, as well as on particles.

69. *Chemical affinity* forces the particles of different substanees to unite and to form compounds, which possess none of the qualities of the original ingredients.

Illus. *Sulphuric acid* and *potash*, in a separate state, are distinguished by qualities entirely different. One is a solid, which being added to blue vegetable infusions, changes their colour to green; the other is a liquid which changes the same colour to red. They are also distinguished by peculiarities of taste, and by their different actions on substances.

If we add one of these bodies to the other, in small quantities at a time, and after each addition examine the compound, we shall finally attain a certain point at which the liquid will possess neither acid nor alkaline qualities; the taste of the compound will be bitter, and it will produce no effect on blue vegetable colours.

Obs. This experiment will serve as an illustration of the effects of chemical action in a great variety of cases. In the instance before us, two of the most caustic and active substances with which we are acquainted, by their combination produce a third which may be handled, or swallowed with perfect safety.

The same effect is produced more or less completely, by adding any of the strong acids, to either of the alkalies, or alkaline earths. Their action on other substances, are weakened, in proportion to the addition, until, at a certain point their caustic qualities cease entirely.

70. When opposing properties are thus destroyed by chemical combination, the two substances are said to *saturate* each other, and the precise point at which this is effected is called the *point of saturation.*

Obs. The caustic properties, of both acids and alkalies, as above stated, are entirely destroyed by saturation. This result is the effect of chemical affinity. The acids and alkalies may be considered as having greater forces of attraction for each other, than either has for any other substance. When once combined, therefore, their mutual attraction does not permit them to leave each other to act on other bodies.

Illus. Nitric acid and potash are each caustic substances. They combine with animal and vegetable matters and destroy them. They burn the flesh, &c. but when they are united, all these active qualities cease, and the mild compound *nitre* is formed. Now these active ingredients are still in existence as may be shown by decomposition ; for if sulphuric acid be added to the nitre, this having a still stronger affinity for the potash than the nitric acid has, the latter acid is set at liberty with all its active properties.

Corol. The neutralizing effect which the acids and alkalies have on each other, is not owing to the destruction of their active principles, but to their strong mutual affinities.

71. In all cases of chemical combination, there happens a more or less evident change of properties, the resulting compound always being in some respects different from the original ingredients.

Illus. 1. When a piece of iron is dipped into a mixture of sulphuric acid and water, each of these ingredients are acted upon. The water is decomposed by the iron, which absorbs its oxygen, and forms an oxide of iron, while the hydrogen is set free, and makes its escape. The oxide is then dissolved by the acid, forming sulphate of iron.

2. On melting together the *red* metal copper, and the *white* one zinc, the *yellow* compound *brass* is formed. It is obvious that by simple mixture the colour of the brass ought to be merely a paler *red* than the copper, this being the case when two paints of these colours are blended together. The new colour therefore must be referred to the chemical union of the two ingredients.

72. In many cases where substances act chemically on each other, the fact is to be known chiefly by observing the phenomena which take place at the time of their action.

Illus. On mixing together *milk* and *water*, we observe no change of temperature, no precipitate, nor any other circumstance which denotes chemical action. We therefore consider this as a *mixture* of the two ingredients.

But when we mix *sulphuric acid* and water, there is produced a degree of heat much above that of boiling water, and at the same time the two substances occupy less bulk than they did when in a separate state. Here then it is inferred, that chemical action has taken place, although the substances have undergone neither change or form of colour.

73. In almost every case of chemical combination, there takes place either a change of *colour*, a change of *specific gravity*, a change of *temperature*, or a change of *form*.

74. Change of colour may be observed in a great variety of cases. The alloys of any two of the metals do not exhibit the medium colour between them. The colours of metallic oxides differ according to the quantities of oxygen which they contain. Thus, 100 parts of quicksilver and 4 parts of oxygen invariably give a *black* compound, while the same quantity of the metal, with 8 parts of oxygen, gives a *red* oxide.

The *purple* infusions of vegetables are instantly turned *green* by alkalies and *red* by acids. Ammonia changes the solution of any of the salts of copper, to blue, &c.

75. Change of specific gravity takes place whenever any two of the metals are melted together, so that they form alloys. In most cases the specific gravity is increased by the union. This is also the case with many of the liquids, as alcohol and water, some of the acids and water, &c.

76. The change of temperature which takes place in consequence of chemical action, is most strikingly illustrated by mixing sulphuric acid and water. The same effect is also produced in a greater or less degree, when any of the stronger acids or alcohol is mixed with water. In many

examples a contrary effect takes place, and a diminished temperature, or production of cold is observed, as when common salt, or any other easily soluble salt, is mixed with ice or snow.

Obs. When heat is produced by mixture, the two substances are found to occupy less space when united than when separate. Thus a pint of sulphuric acid and a pint of water do not, when poured together, make a quart. There is consequently an increase of density. On the contrary, when substances, on being mixed, pass from a solid to a fluid state, heat is absorbed, and cold is produced, as in the example of mixing salt and ice. *See Caloric.*

77. The forms of bodies are often materially changed by chemical combination.

Exp. 1. If equal parts of alum and sugar of lead be rubbed together forcibly in a mortar, they change from the solid to the semifluid form.

The cause of this change of form admits of an easy solution. The bases of the two salts having an affinity for each other, they combine on being rubbed together, while the water of crystalization, which had become solid by its previous union with them, is set free, and thus occasions the partial fluidity.

2. Mix with a saturated solution of muriate of lime in water, a small quantity of sulphuric acid, and the two liquids will become solid.

This change of form is thus explained. The water remains fluid after dissolving a large quantity of muriate of lime. When the sulphuric acid is added, the lime quits the muriatic acid and unites with it and forms a sulphate of lime. This latter salt being insoluble in water, takes a spongy solid form, occupying most of the vessel in which the experiment is made.

78. Elective affinity. An important law of affinity, which is the basis of almost all chemical theory, is, that one substance has not the same force of affinity towards a number of others, but attracts them unequally. Thus A will combine with B in preference to C, even when these two are presented to A under equally favourable circumstances. Or when A is united to C, the application of B will detach A from C, and we shall have a new com-

pound of A and B, C being set at liberty. Such cases are examples of *single decomposition.*

Illus. Into a solution of muriate of lime, let fall a few drops of sulphuric acid. The *muriate* will be decomposed, a *sulphate* of lime will be formed, and the muriatic acid will be set free.

Now if we call the muriatic acid A, and the lime B, we shall have A and B combined, forming *muriate of lime.* On adding the sulphuric acid C this first combination is destroyed, because B has a stronger affinity for C than it has for A, consequently B and C unite, while A remains alone in the solution.

79. The force of affinity which one body has for another, is so different and obvious, as to admit of the construction of tables, showing at a single view, what substance will decompose a primary compound, and what again will decompose this, and so on.

Obs. Thus, taking muriatic acid as a substance for which several of the alkalies and earths have affinities, the relative forces of attraction will be thus ; placing that which attracts it most strongly at the top, and that for which it has the weakest affinity at the bottom.

MURIATIC ACID.
Barytes.
Potash.
Lime.
Ammonia.
Magnesia, &c.

Tables of this kind, on an extensive scale, are of great use to the practical chemist, as they show at once what substances will decompose any given compound, as well as what are incompatible with each other on this account.

In the present example, magnesia, being placed lowest in the scale, shows that when this is united to muriatic acid, the salt, muriate of magnesia, would be decomposed by ammonia, because of the two, ammonia has the strongest affinity for the acid. By adding ammonia, therefore, to muriate of magnesia, the magnesia would be precipitated and muriate of ammonia would be formed. By adding lime to a solution of muriate of ammonia, the ammonia would be precipitated and a muriate of lime would be formed, and so of the others.

Obs. No chemical facts can appear, on first view, more simple, or intelligible, than those which are explained by the operation of single elective affinity. It will be found, however, on a more minute examination, that this force, abstractly considered, is only one of several causes which are concerned in chemical decompositions, and that its action is modified, and sometimes even subverted by counteracting forces.

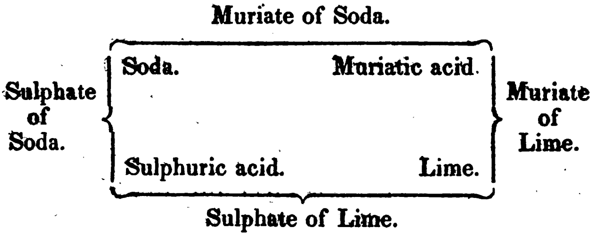
80. Although it is ascertained that the affinities of one body for a number of others are not all of the same degree of force; we are yet ignorant *how much* the affinity of one body for another is superior to that of a third. The determination of the precise forces of affinity would be an important step in chemical philosophy, for its phenomena would then be reduced to calculation, and we should be enabled to anticipate the results of experiment.

Obs. That the force of chemical affinity must be prodigiously great, is evident from its effect in preserving the combination of water with some bodies, as the alkalies, when exposed to a violent heat.

Illus. Notwithstanding the great expansive force of heat and the ease with which uncombined water is turned into steam and driven off by it, it appears that in some instances the force of attraction is still greater, for, on submitting potash, or soda to the most violent heat of a furnace, they still retain a quantity of water, though water is not essential to the constitution of these bodies.

81. COMPLEX AFFINITY, *or double elective affinity*, is exerted whenever two compound bodies mutually decompose each other, and by a double interchange of ingredients, form two *new* compounds.

Obs. It frequently happens that the compound of two principles cannot be destroyed either by a third or fourth separately applied; but if the third and fourth be combined, and placed in contact with the former compound, a decomposition, or a change of principles will ensue. Thus when lime is added to a solution of sulphate of soda, no decomposition happens, because the sulphuric acid attracts the soda more strongly than it attracts lime. If muriatic acid be applied to the same compound, still its principles remain undisturbed, because the sulphuric acid attracts soda more strongly than the muriatic acid does. But if the lime and muriatic acid previously combined be mixed with the sulphate of soda a double decomposition is effected. The lime leaving the muriatic acid, unites with the sulphuric acid; and the soda, being separated from the sulphuric acid, combines with the muriatic. These decompositions are rendered more intelligible by the following diagram.



On the outside of the vertical brackets are placed the original compounds, sulphate of soda and muriate of lime; and above and below the diagram, the new compounds. The upper line being strait, indicates that the muriate of soda remains in solution, and the middle of the lower line being directed downwards, shows that the sulphate of lime is precipitated.

Obs. The turbid, or milky appearance which is seen on adding the clear solutions of muriate of lime and sulphate of soda together, is owing to the fact that one of the newly formed salts, sulphate of lime, is insoluble in water, and consequently is precipitated, or falls to the bottom of the vessel, occasioning in its descent the turbidness. The same appearance is seen in every case where an insoluble precipitate is formed by chemical decomposition.

82. EXPERIMENTS illustrating chemical affinity.

Exp. Mix together some olive oil and water in a vial. The oil will rise to the top of the water, and cannot be made to unite with it, there being no affinity between them. But if some pieces of potash be added, and the vial shaken, there takes place a chemical union between the three substances.

Obs. The potash having an affinity both for the oil and the water, it attracts each with a force sufficient to effect their union. In this manner *soap* is formed.

83. Some bodies do not act on each other unless either one or both are in a state of solution, or at least contain water.

Illus. Spread thinly, on a piece of tin-foil three or four inches square, some dry nitrate of copper, and wrap it up. No effect will be produced. Unfold the tin-foil, and having sprinkled the nitrate of copper with the smallest possible quantity of water, wrap the tin-foil up again as quickly as possible, pressing down the edges closely. Considerable heat, attended with copious red fumes, will now be excited ; and if the experiment has been dexterously made, sparks of fire or even flame will be emitted.

Obs. This shows that nitrate of copper has no action on tin, except it is in a state of solution.

84. Experiments illustrating single elective affinity.

Exp. 1. Add to a solution of soap in water a few drops of sulphuric, or any other acid. The acid will combine with the potash ; the oil will be set free, and will rise to the top.

Obs. The same effect is produced by those waters which naturally contain a small quantity of any acid, as the carbonic. These waters are called *hard*, and will not wash, because the acid which they contain decomposes the soap.

2. To a solution of camphor in spirits or alcohol, add a quantity of water. The mixture will instantly become white and turbid, and the camphor will rise to the top in flakes.

Obs. The alcohol has a stronger attraction for the water than it has for the camphor, it therefore leaves the latter and unites to the former, while the camphor, being insoluble in water, takes the solid form, and rises to the top, because it is of less specific gravity than the fluid.

85. The properties characterizing bodies when separate, are destroyed by chemical combination, and new properties appear in the compound.

Illus. Thus muriatic acid and lime, which in a separate state have a most corrosive taste, lose this entirely when mutually saturated ; the compound is extremely soluble, though lime itself is very difficult of solution : the acid no longer reddens syrup of violet, nor does the lime change it as before to green. The resulting compound, muriate of lime, also exhibits new properties. It has an intensely bitter taste ; is susceptible of crystalization, and the crystals, when mixed with snow or ice, generate a degree of cold sufficient to freeze mercury.

OF THE GASES.

Def. The name *gas* is given to all the permanently elastic fluids, except the atmosphere, which is called *air*.

86. The gases are a numerous set of bodies, obtained from various substances, chiefly by chemical decompositions. They differ greatly from each other in some of their properties, in others, they are nearly alike. Thus some are acid, some are alkaline; some extinguish flame, and some support combustion, &c. But they all agree in respect to that ærial form, and that elasticity which constitute them gases.

87. The gases are supposed to consist of solid ponderable particles united chemically to caloric, and perhaps to electricity also. The weight of the gases depends on their solid particles; their elasticity on the repulsive power of caloric to which these particles are united.

Obs. 1. All the gases agree in the ratio of their expansibility by equal increments of heat. This is one part in 480 for every degree of Farenheit's scale between the freezing and boiling points.

2. The bulk of a gas is inversely as the pressure which it sustains. Thus the air (which is composed of two gases) at the earth's surface, sustains a pressure equal to the weight of the incumbent atmosphere, which is nearly equivalent to a column of mercury 30 inches high. If we double this pressure we reduce the air to one half its bulk; if we triple it, to one third, and so on in this proportion to any known extent. On the contrary, if we remove one half the pressure, we double the bulk of air, and if we remove nine-tenths of the pressure, we increase the bulk ten times, and so in this proportion, to any imaginable extent.

All the gases are absorbed, in greater or less quantities, by porous substances. Charcoal possesses the highest absorbent power, but all substances possessing a certain degree of porosity, after being exposed to the action of the air-pump, absorb certain quantities. The quantity absorbed by charcoal, depends on the gas to which it is exposed. Thus a piece of red hot charcoal, quenched by plunging it under mercury, absorbs 90 times its bulk of ammoniacal gas, but hardly twice its bulk of hydrogen gas. The other gases are absorbed in proportion between these.

All the gases are also more or less absorbable by water. Thus water absorbs several hundred times its bulk of sulphurous acid gas, but only a very minute quantity of nitrogen.

Remark. The gases are probably very numerous. The number known at present is 43. The following table contains the most important and curious among them. The right hand column shows the composition of the gases on the left The cross + signifies "combined with;" as *ammonia* is composed of 3 parts of hydrogen combined with 1 part of nitrogen.

CLASS I.

Gases with simple or single bases.

Oxygen gas. Nitrogen gas.
Hydrogen gas. Chlorine gas.

CLASS II.

Gases with compound bases.

DIVISION I.

Compound combustible gases.

		Composed of	*by volume.*	
	Name	*parts*		*parts*
1	Ammonia	3 hydrogen	+	1 nitrogen.
2	Carburetted hydrogen	1 carbon	+	2 hydrogen.
3	Olefiant gas	1 carbon	+	1 hydrogen.
4	Sulphuretted hydrogen	1 hydrogen	+	1 sulphur.
5	Phosphuretted hydrogen	1 phosphorus	+	1 hydrogen.

DIVISION II.

Oxides in the state of gas.

		parts		*parts*
1	Carbonous oxide	2 carbon	+	1 oxygen.
2	Nitrous oxide	1 oxygen	+	2 nitrogen.
3	Nitric oxide	1 oxygen	+	1 nitrogen.

DIVISION III.

Acid gases.

	parts		*parts*
Carbonic acid	1 carbon	+	1 oxygen.
Sulphurous acid	1 oxygen	+	1 sulphur.

	parts.		parts.
Nitrous acid	3 oxygen	+	2 nitrogen.
Nitric acid	5 oxygen	+	2 nitrogen.
Muriatic acid	1 hydrogen	+	1 chlorine.
Fluoric acid	oxygen, with unknown base.		

Obs. The method of making experiments on the gases is described under the head of " Chemical Utensils," article " gas apparatus."

OXYGEN GAS.

88. We have no knowledge of the properties of oxygen, except in a state of combination. It sometimes exists in a solid state, as when it combines with the metals to form oxides, and sometimes in an aeriform state, as when it is united to caloric and light, forming oxygen gas. No process has yet separated the oxygen from the solid, and the aeriform state at the same time; the consequence is, that the base, or ponderable part of oxygen has never been examined in a separate state.

89. Oxygen is an invisible fluid, like air. It has neither taste nor smell. Its specific gravity is 1103, air being 1000. It is slightly absorbed by water. It is procured from a great number of substances; and forms about one-fifth of the atmosphere.

Exp. Take a quantity of *black oxide of manganese*, put it into a retort, or Florence flask, furnished with a tube, (see chemical utensils) and pour on one half its weight of sulphuric acid: mix them together, and place the retort, or flask over an Argand lamp. The gas comes over in abundance, and may be collected over water in the usual way, by plunging the beak of the retort, under a vessel filled with it. See *gas apparatus*.

Caution.—When bubbles of oxygen cease to ascend up the water in the receiver, the retort must be removed, otherwise it will be broken by the water which will be forced over to fill the vacuum caused by the heat.

Obs. The above, is the most convenient method of collecting oxygen gas in the small way, and for ordinary experiments; where larger quantities are wanted, other methods are used.

90. Oxygen gas may also be obtained from black oxide of manganese, heated to redness in an iron retort, or gun barrel:

91. From red lead, heated in the same way.

92. From nitrate of potash, (common salt petre) also heated as above.

93. From the leaves of plants, exposed to the action of the sun, under a receiver filled with water, &c.

91. All combustibles burn in this gas with greatly increased splendour.

Exp. 1. Fill a glass vessel, as an open-mouthed vial, with this gas; then as it stands on the shelf of the water-bath, slide a plate of glass under its mouth and set it upright, keeping the glass in its place. Have ready a wax-taper fixed to a piece of wire; light the taper, and sliding the plate of glass hastily off, plunge it into the gas. The taper will burn with intense brilliancy.

95. If the taper be blown out, and instantly be plunged into the gas, it will be lighted again, with a slight explosion.

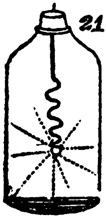
Obs. As tapers, ready made, cannot always be obtained, it was thought worth while to add here, that a strip of cotton cloth, or some cotton wick, dipped in melted bees-wax, and rolled moderately hard while the wax is cooling, will answer every purpose.

96. Several of the metals, when heated in a vessel of oxygen gas, inflame, and burn with great brilliancy.

2. Take some thin pieces of zinc, such as are made by melting that metal, and pouring it into water; place a small quantity of them on a spoon, or small dish, made by hammering a piece of tinned iron concave, and fixing to it a wire handle. Place in the midst of the zinc a grain, or two, of phosphorus; then set fire to the phosphorus, by holding the dish over a candle, and instantly plunge it into a vessel of oxygen gas. The zinc will be inflamed and will burn with a beautiful white light.

3. Procure some iron, or what is better, steel-wire, or a watch-spring; wind it round a slender rod of glass, or wood, so as to coil it up in a spiral form: the turns of the wire being about the eighth of an inch apart. Then withdraw the rod, and tie

to the end of the wire a piece of thread, dipped in melted sulphur, or bees-wax; leave the other end of the wire strait for a few inches, which must be fixed to a cork, in such a manner that the coil will hang vertically when the cork is in its place.



Fill a bottle, holding about a quart, with oxygen gas, and set its mouth upwards, covering it with a plate of glass. Then light the sulphur, or wax, and introducing the coil into the bottle, put the cork in its place. Fig. 21. The iron will burn with an inconceivably brilliant light, throwing out sparks in all directions. Now and then a globule of the melted iron falls down and will break the bottle unless some sand or water be left at the bottom. See fig.

97. All bodies, by combustion in oxygen gas, acquire an addition to their weight.

Illus. If the wire, in the last experiment be nicely weighed before it is burned, and afterwards if the globules of oxide of iron be weighed, it will be found that they weigh more than the same quantity of iron did before burning.

Expl. The iron, in burning, absorbs the solid ponderous particles of the oxygen gas, which become a part of the oxide, while the light and heat, with which the gas was combined, is given out.

Oxygen gas changes the colour of blood from black to red.

Exp. Put a little dark-coloured blood into a vial of oxygen gas, and shake the vial, the colour will be changed to red.

Oxygen gas is the principle of acidity.

Exp. Introduce some burning sulphur under a bell glass, filled with this gas, standing in a dish, over a small quantity of water. The sulphur, as it burns, absorbs the oxygen and forms with it sulphuric acid, which is absorbed by the water; hence the water will be sour.

OF NITROGEN OR AZOTIC GAS.

98. The term *Nitrogen* is compounded of two Greek words, which signify "to generate nitre." *Azot*, which is used to signify the same substance, means "life depriver," because it destroys the life of any animal which is forced to breath it.

99. Nitrogen is principally distinguished by its negative properties. It destroys the lives of animals immersed in it, and instantly extinguishes

flame. It has no sensible taste. It is a component part of all animal substances. When united to oxygen in a certain proportion, it forms atmospheric air.

100. Nitrogen gas may be obtained by various methods, and from a variety of substances.

Exp. 1. Mix equal weights of iron filings and sulphur into a paste with water, and place the mixture in a proper vessel over water, supported on a stand; then invert over it a bell glass full of common air, and allow them to stand in this situation a day or two. The paste absorbs the oxygen from the air contained under the jar, while the nitrogen remains.

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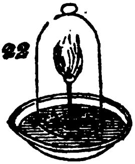


2. Place on a stand in a shallow dish of water, fig. 22, a piece of phosphorus. Set fire to the phosphorus by touching it with a hot iron, and immediately invert over it a bell of glass. The phosphorus absorbs the oxygen by combustion, and the nitrogen remains.

3. Put some lean meat into diluted nitric acid, and by the action of the acid on the meat, nitrogen will be extricated.

101. Nitrogen gas has the following properties. It immediately extinguishes a lighted taper.

Exp. Fill a small jar with this gas, and set it upright, with a cover on the mouth; light a taper, and partly removing the cover, plunge it into the gas. The light will be instantly extinguished.

102. It destroys animal life.

Exp. Confine an insect, or any animal in it, and it soon dies.

OF COMMON OR ATMOSPHERIC AIR.

103. By air is meant any portion of that elastic fluid, of which the atmosphere is chiefly composed, excluding the water and other foreign substances which it contains. At this place the air is to be considered chiefly in a chemical point of view, without regard to the physical effects or properties of the atmosphere at large.

104. The air in which we live is a permanently

elastic fluid; invisible, indeed, but easily recognised by its motion, or its resistance to motion.

Obs. It is composed of two gases, oxygen and nitrogen, probably in a state of chemical combination. The oxygen composes about one-fifth, and the nitrogen four-fifths of the atmosphere. When these two gases are separated, their properties are found to be totally unlike each other; the oxygen being eminently fitted to support combustion and life, while the nitrogen extinguishes flame and destroys life.

105. As we are not acquainted with any substance which will decompose the air, by combining with the nitrogen, while the oxygen remains in its elastic state, we are obliged, in all cases, to separate the two gases by such substances as abstract the oxygen from the nitrogen. All combustibles are capable of doing this, with greater or less facility. Thus during the burning of a candle, oxygen is separated from the nitrogen, and it is on this circumstance alone, that its combustion depends. The oxidation or rusting of iron depends on the same principle, and in this respect may be considered a slow combustion.

106. The analysis of the air, then, consists in a process by which the oxygen is absorbed, while the nitrogen remains behind, and thus the diminution of bulk will show the proportions of each.

Exp. On a stand, placed in a dish of water, put a grain or two of phosphorus; set fire to the phosphorus by touching it with a hot iron, and instantly invert over it a bell glass. By the combustion of the phosphorus, all the oxygen will be absorbed, while the nitrogen remains in the receiver, and in consequence of the absorption, the water will rise in the receiver.

Obs. If the air remaining in the glass be examined by introducing into it any lighted body, as a taper, it will instantly be extinguished, showing the entire want of that principle which supports combustion. If an animal be put into it, it soon dies.

107. To determine the quantity of oxygen absorbed, an instrument is made use of, called the *Eudiometer;* and the art, or method of ascertaining

the purity of the atmosphere, is called *Eudiometry.*

Obs. 1. Various instruments have been invented for this purpose, and several substances have been employed to absorb the oxygen.

2. One of the most simple Eudiometers consists of a glass tube of an inch in diameter, and 24 inches long, divided into one hundred equal parts. The scale may consist of a piece of paper pasted on, after which it must be varnished to protect it from the water. The tube is closed at one end. Into such a tube, full of common air, put a piece of phosphorus, and stop the open end carefully with a cork ; then heat the part where the phosphorus lies, over a lamp ; it will burn rapidly. Let the tube get cold and heat it again ; then when it gets cold, put the end stopped with cork under water, and withdraw it so that the water can enter and fill the space left by the loss of the oxygen. The water will rise up in the tube and show what proportion of oxygen has been absorbed, and what proportion of nitrogen remains. Experiments of this kind have determined that the atmosphere consists of 21 parts of oxygen and 79 parts of nitrogen to the 100.

3. It is remarkable, that on examining specimens of air in all countries, and from almost every part of the globe, no perceptible difference in the composition of the atmosphere has been detected.

108. The *synthesis* of the atmosphere consists in mixing in proper proportions the gases of which it is composed, and then submitting the mixture to the action of a burning body.

Exp. Take two bell glasses, of equal capacities, and fill the one with oxygen and nitrogen, in the proportions of 21 parts of the former, and 79 parts of the latter ; fill the other with common air. Invert both at the same instant over two tapers of the same size, and burning alike. The phenomena observed in both will be exactly alike. They will both give out the same quantities of light, and will go out at the same time.

109. The respiration of animals produces the same effect on atmospherical air, that combustion does : when an animal is included in a limited quantity of air, it dies as soon as the oxygen is consumed ; and no gas will maintain animal life but oxygen, or a mixture which contains it.

Obs. Experiment shows that life cannot be sustained where a combustible body will not burn; hence a good precaution for those who descend into wells, or other places where foul air might be suspected, would be, first to let down a burning candle. If this will not burn, certain death would attend the descent.

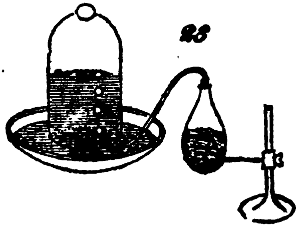
The atmosphere is partly supplied with oxygen by the growth of plants. See Vegetation.

OF HYDROGEN GAS.

110. The term hydrogen is derived from two Greek words, and signifies "to become," or "produce water," because when combined with oxygen, it forms water.

111. Hydrogen, in a separate state, has never been examined; its affinity for caloric being so strong as to give it the form of a gas, whenever it is separated from its other combinations. In the form of a gas, hydrogen is a permanently elastic fluid, possessing very peculiar properties.

112. By the union of its base with the base of oxygen, water is formed, while the light and heat of both are given out. It is the lightest of all substances whose weight we are able to estimate. It is not fitted for respiration. It is obtained by the decomposition of water, from which alone it originates.



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Exp. 1. Take some zinc, granulated by melting and pouring it into water, or some iron wire, or iron filings, put it into a retort or flask, fig. 23, and pour on sulphuric acid, diluted with five or six parts of water. A violent effervescence will ensue, owing to the escape of the gas through the water. The gas may be collected in the usual manner. See fig.

Obs. The production of hydrogen by the above experiment, depends on the decomposition of the water, by means of the zinc, or iron and the sulphuric acid. The metal has an attraction for oxygen, which it obtains from the water ; this forms an oxide of the metal, which is instantly dissolved by the acid ; the surface is thus left clean, and exposed to the water from which it attracts another portion of oxygen, which is dissolved as before. In consequence of the absorption of the oxygen from the water, the hydrogen is set free, which, uniting with caloric, appears in the form of hydrogen gas.

Exp. 2. Place a gun barrel in a furnace so as to heat it red hot in the middle ; connect to one of its ends, by means of a tube, a retort placed over an Argand lamp ; to the other end, fix a tube which goes under a vessel inverted in the water-bath. Make the water in the retort boil so that the steam may pass through the red hot gun barrel. Hydrogen will be produced, and will pass into the inverted vessel.

Obs. Red hot iron has a strong attraction for oxygen. In the last experiment the oxygen of the water unites to the iron, while the hydrogen being set free, unites to caloric, and is obtained in the form of hydrogen gas.

113. Hydrogen is about 13 times lighter than air. Its levity may be shown in various ways.

Exp. 1. Fill with this gas a bladder, furnished with a tube and stop-cock, and adapt to this a common tobacco-pipe. Dip the bowl of the pipe into a strong solution of soap in water, and by pressing the bladder blow up bubbles. These, instead of descending to the ground, will rise rapidly in the air.

Obs. It is with this gas that balloons are filled. They rise through the air on the same principle that a dry piece of wood rises through water, or that a leaden bullet will rise through quick-silver, viz. by being of less specific gravity than the fluid which surrounds them.

Exp. 2. The above experiment may be varied by charging the bladder with two parts of hydrogen and one of oxygen gas. Bubbles blown with this mixture, take fire on being touched with a lighted taper, and detonate with a loud report.

Caution. Detach the bubble completely from the pipe before it is touched by the taper, otherwise a dangerous accident may happen from the explosion of the contents of the bladder.

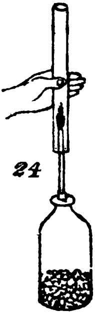
114. This gas, though inflammable itself, extinguishes burning bodies.

Exp. 3. Fill a small jar or tumbler with it, and keeping the vessel inverted, bring it over a burning taper ; then suddenly depress the vessel so as to surround the light with the gas. The taper will instantly be extinguished.

Obs. Hydrogen gas burns only at the point of contact with the atmosphere, or with oxygen gas. In other words, it is combustible only as it unites with oxygen. Hence, in the last experiment, the taper was extinguished because being entirely surrounded by the hydrogen, no oxygen come to support its combustion.

115. When a stream of hydrogen gas is burned within a tube of glass, porcelain, or metal, musical tones are produced.

Exp. 4. Into a convenient vessel, fig. 24, as a glass bottle, put the materials for making hydrogen. Procure a glass, or metallic tube, with a bore about the size of a small pin ; pass the tube through the cork of the bottle, and inflame the gas at the end of the tube. Then take a glass tube about 18 or 24 inches long, and from one to two inches wide, and including the flame within the bore, pass it down until the tones are produced. The tones will be varied as the tube is raised or depressed, or by using those of different sizes.



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Caution. Take care not to inflame the hydrogen until all the common air has passed out of the bottle, otherwise an explosion may happen.

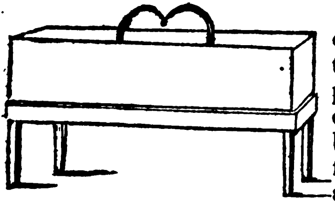
116. Whenever hydrogen is burned, water is produced.

Exp. Let hydrogen be burned at the end of a small orifice, as in the last experiment, and instead of the glass tube, hold over it a tall receiver, perfectly dry. In a few minutes the receiver will be covered with a fine dew.

COMPOUND BLOW-PIPE.

117. If two parts of hydrogen and one of oxygen be burned together, as they issue from a small orifice, a very intense heat will be produced.

Obs. The apparatus made use of for this purpose, is called the *compound blow-pipe*, and may be constructed as follows :



First, provide a tank, or water cistern, in size proportioned to the object for which the blow-pipe is intended. For private experiments, or schools, this may be five feet long, two and a half feet deep, and two feet wide, and made of well seasoned pine boards and covered with two or three coats of paint.

Second, the *gas-holders* may be made of tin or wood, but tin, painted, is much the best. These are square boxes, open at the bottom, and made to fit each end of the cistern, leaving the space of a foot between them. The boxes are fastened to their places by buttons, to prevent their rising when filled with gas.

Thus far the apparatus will serve for a pneumatic cistern, and may be used for making a great variety of experiments, where the use of a water-bath is required.

Third, the blow-pipe consists of two tubes of brass, similar in shape to the common blow-pipe, but each of them bent in form of a semi-circle, with the small ends soldered together. (See fig.)

This part of the instrument requires very nice woskmanship. The two gases must meet only at the extreme point of the blow-pipe, the tip of which is made of platina, or silver, and screwed on. The two orifices must therefore be continued from each of the brass pipes nearly through the tip of platina, at the point of which they meet and come out at a single aperture. The size of this must not exceed that of a common sewing needle.

The other ends of the two pipes are fastened by coupling screws to each of the gas-holders, so that the blow-pipe can be put on or taken off at pleasure. Each leg is also furnished with a stop-cock, by means of which the gases are let into the blow-pipe, and the quantity regulated so as to produce the most intense heat.

The necessity of making the tip of platina, or silver, arises from its liability to melt or oxydate, if made of other metals; and it is a curious fact, lately verified by experiment, that in constructing it, if both orifices meet at any considerable distance from the point, the gases will not burn, the hydrogen being extinguished on letting in the oxygen.

OF WATER.

118. Water is composed of two parts of hydrogen, and one of oxygen.

Obs. It has been stated under the article hydrogen, that when that gas was burned, water was always produced. The burning of hydrogen consists in its rapid union with oxygen, and the simultaneous extrication of the light and heat with which they were united, so long as they remained in their gaseous states. The water, then, which is so produced, is a compound formed by the combination of the two substances, oxygen and hydrogen. It is not, however, a compound of the two gases, but only of their bases, or solid ponderable parts. As gases, these solid particles were united to caloric, which gives them their properties as elastic fluids. When they unite, this caloric is given out, and takes the form of sensible heat, and their particles uniting, form water.

119. That water is composed of these two substances, can be shown in two ways, viz: by *synthesis*, or the joining of its elementary ingredients, and by *analysis*, or the separation of its constituent particles.

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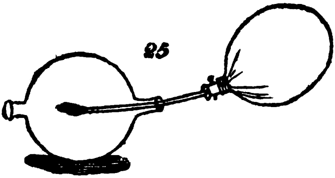


Exp. 1. Fill with hydrogen gas a bladder furnished with a stop-cock and tube. Inflame the hydrogen and introduce the tube into a large glass globe with two openings, so that the flame will be in the centre of the globe, (see fig. 25.) As the hydrogen burns, the rarified and vitiated air will pass off at one of the openings, while the other admits fresh air to support the combustion. In a few minutes, the globe, which should be perfectly dry at the beginning of the process, will be covered with a moisture on the inside, and by continuing the experiment, the water will run down its sides.

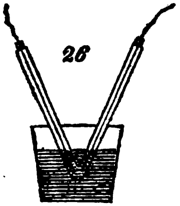
2. Expose to the intense cold of winter, a lamp burning in a glass lanthorn of about four inches diameter. The sides of the lanthorn will be covered with ice. The burning of the lamp forms water, the hydrogen being furnished by the oil, while the oxygen is absorbed from the air of the atmosphere.

Obs. When accuracy is required in the formation of water, the two gases, hydrogen and oxygen, are burned together in a close vessel over mercury. When the two gases are burned in this way, in the exact proportions in which they exist in the composition of water, they both entirely disappear, and a quantity of that fluid is the result of the experiment.

120. The analytical experiments on water, are of two kinds, viz. such as present us with one ingredient only, in a separate and distinct form: and such as present us with its two component principles, the oxygen and hydrogen, mixed together in the state of gas.

Obs. The method of decomposing water by means of zinc and sulphuric acid, for the ordinary purpose of collecting hydrogen, has already been described. Water may also be decomposed by passing its steam through a red hot gun barrel, containing coils of iron wire, or by passing it through a porcelain or iron tube, containing red hot charcoal. In these cases, however, only the hydrogen is obtained in the gaseous form, the oxygen having entered into union with the iron wire, or the charcoal.

121. The process by which the elementary parts of water are separated from each other, and are both obtained in an aeriform state, as hydrogen and oxygen gases, are dependent on the agency of electricity. The two gases may be obtained in a separate state by a proper apparatus.



Exp. Bend a glass tube into the form of a syphon, as seen in fig. 26. At the outer angle of the bend, a small hole must be ground so as to let in the water. Both ends of the tube are stopped with corks, through each of which passes a wire, one from the positive and the other from the negative end of a galvanic battery. The wires pass down nearly to the angle of the tube, as in the figure. They must be made of a metal not oxidable, as gold, or platina. The tube is filled with water, and the bended part immersed in a dish of the same fluid.

122. When a stream of galvanism is made to pass through the water between the points of the two wires, by connecting these with each end of the battery, the water is decomposed, and the two gases rise in a separate state, into the legs of the

tube, oxygen being found in the leg connected with the positive wire, and hydrogen in the other.

Obs. If after the above experiment, the contents of each tube be taken and burned, water is again formed; so that these two processes afford the most positive proof that water is composed of oxygen and hydrogen.

123. Water is often decomposed in small quantities by being kept for a long time in wooden vessels.

Obs. The wood combines with its oxygen, and probably with a part of its hydrogen, and again gives out *carburetted hydrogen*, hence the disagreeable smell which is emitted from water long kept in casks. If the cask is charred on the inside, as is now done preparatory to putting up water for long voyages, this effect is not produced.

OF CHLORINE OR OXYMURIATIC ACID GAS.

124. This gas is of a greenish yellow colour, and hence its name, the Greek word from whence it is derived signifying *green*. It has an extremely pungent and suffocating smell, so that it is not only disagreeable, but dangerous to breathe only a few bubbles of it. It is more than twice as heavy as air. At the temperature which congeals quicksilver it takes the liquid form, and is condensed on the sides of the vessel. It is obtained by the following process:

Exp. Into a tubulated retort introduce eight ounces of muriatic acid, and three ounces of finely powdered black oxide of manganese, and apply the heat of a lamp. The gas may be received over water in the usual way.

Caution. Great care must be taken not to let the smallest quantity escape in the room.

125. Chlorine gas, when perfectly dry, has no effect on dry vegetable colours. But in its ordinary state, as when collected by the above process, all vegetable colours are destroyed by it.

Exp. 1. Introduce into a receiver of this gas a piece of paper stained with litmus, or tincture of red cabbage, or some of the purple paper which surrounds loaf sugar. In a few minutes the colour will be discharged. The colours of flowers, as a rose, will be discharged in the same way.

Obs. The property which chlorine has of discharging colours, first suggested the idea of its employment in the bleaching of cotton and linen goods, and it is now extensively employed for these purposes.

126. Most of the metals, when introduced into this gas in a state of minute division, inflame spontaneously.

Exp. 2. Fill a deep bottle with this gas and set it upright, with the mouth covered. If a little sand be poured into the bottle, it will prevent its breaking. Have ready some antimony in powder; slide the cover off and pour in the antimony. The metal will take fire before it reaches the bottom, and will burn with a white and beautiful flame. Gold or silver leaf, thin plates of copper, iron filings, &c. will take fire in the same way.

127. When a mixture of chlorine and hydrogen is exposed to the direct rays of the sun, it explodes with great violence.

Exp. Mix equal volumes of chlorine and hydrogen in a glass bottle, taking care to do this in a darkened room. Then cover the bottle to protect it from the light and carry it out of doors, and contrive to uncover it, while standing at a few rods distance, as by means of a string, or otherwise. The mixture will explode and burst the bottle, which will fly in every direction.

Caution. Although it has heretofore been stated that this mixture would not explode except in the direct rays of the sun, it has lately been proved by Professor Silliman, that the diffuse light of day, even when the sun is obscured, as during a snow storm, is sufficient to explode it.

Note.—Chlorine is placed among the simple substances, in obedience to some of the latest and most eminent English authorities. There is however still a dispute among chemical philosophers whether it be a simple body, or a compound of muriatic acid and oxygen. The reader will find the question discussed in Cooper's Thomson's Chemistry, in Ure's Dictionary of Chemistry, in Silliman's Journal, and in several of the English journals.

OF THE SIMPLE SOLIDS.

OF IODINE.

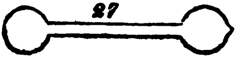
128. The name of this substance is derived from the colour of its vapour, which is a beautiful violet, *iodine* signifying this colour. Iodine was accidentally discovered at Paris in the year 1812. So far as is known, it is a simple body. Its form is that of scales, resembling those of micaceous iron ore. Its colour bluish black, with a metallic lustre. Its taste is very acid and it is a strong poison. When applied to the skin it leaves a yellow stain.

Obs. This substance is obtained from the ley made from the ashes of marine vegetables, or from the substances called *kelp* or *barilla*, which are impure mineral alkalies.

Exp. Dissolve the soluble part of kelp in water, concentrate the liquor by evaporation, and separate all the crystals that can be obtained. Pour the remaining liquor into a clean vessel, and mix with it an excess of sulphuric acid. Boil this liquid for sometime, then decant, and strain it through a cloth. Put the liquid into a small flask, and mix with it as much black oxide of manganese by weight as there was sulphuric acid. Then attach to the mouth of the flask a glass tube, closed at the upper end, and apply the heat of a lamp to the flask. The iodine sublimes and attaches itself to the glass tube.

129. Iodine, when heated to about 250 degrees, takes the form of a gas of a most beautiful violet colour.

Exp. Put a few grains of iodine into a glass tube terminated by a bulb, and stop the other end with a cork If the tube be gently heated at the part where the iodine lies, it sublimes, and fills the tube with the violet coloured gas, which again attaches itself to its sides where the heat is least, in the form of minute shining scales. When the tube is cold nothing appears in it except the small shining scales, but whenever it is heated it is instantly filled with the violet air, and this may be repeated any number of times.



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A more pleasing and permanent instrument would be a glass tube with two bulbs, (see fig. 27,) enclosing a few grains of iodine, and hermetically sealed. A combination of iodine with mercury has been proposed for a pigment, and a certain preparation of it has been used in medicine : in other respects it has not been applied to any useful purpose.

OF PHOSPHORUS.

130. Phosphorus is an inflammable substance and is distinguished by the following external characters. The colour is flesh red; it is soft and easily yields to the knife. It melts at about 90 degrees Fahrenheit, and when perfectly dry inflames at 140 degrees. In the atmosphere it emits a white smoke, which is luminous in the dark.

131. Phosphorus is obtained from the bones of animals by a long and intricate process.

Caution. In making experiments with this substance great care is necessary. If it inflames in contact with the skin, it sticks close, and cannot be shaken off, and will consequently produce a deep burn. Sometimes it will inflame with merely the heat of the hand ; great caution therefore ought to be taken in cutting, or handling it, lest a small piece get under the nail, or on the hand, where it might occasion a serious accident.

132. Phosphorus may be set on fire by friction.

Exp. Rub a small bit between two pieces of brown paper and it will inflame.

133. In oxygen gas it burns with a most brilliant and beautiful white light.

Exp. Fill a glass jar, or wide-mouthed vial with oxygen gas, and set it upright, having its mouth covered with a plate of glass. Prepare a kind of spoon, made of a small piece of tin and a handle of wire. On the bowl of this, place a grain or two of phosphorus ; inflame it, and instantly plunge it into the oxygen gas.

134. Phosphorus at common temperatures attracts oxygen from the atmosphere, undergoes a slow combustion, and in consequence gives out light and forms phosphorus acid.

Exp. 1. Wrap a piece of phosphorus in wet paper, to prevent the heat of the fingers from setting it on fire ; then write with it on a sheet of the purple paper which surrounds loaf sugar. If this be carried into a dark room the characters will appear beautifully luminous. After the combustion has ceased, it will be seen that the characters are still legible, the colour being destroyed or changed by the phosphorus acid.

2. Put a piece of phosphorus into a small vial half filled with olive oil; then warm the bottom of the vial so as to melt the phosphorus; shake the vial now and then, keeping the mouth covered. This forms *liquid phosphorus*. If the vial is first warmed, by holding it in the hand, and then the cork be removed so as to let in the air, it becomes so luminous as to show the hour of night by a watch. This oil may be rubbed on the face, or hands, with safety, and will give a very singular appearance in the dark.

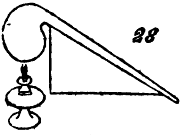
3. Fold a small piece of phosphorus in a piece of paper; lay it down, and strike it with a hammer. The friction produced by the blow will set it on fire.

4. Take 8 or 10 grains of oxymuriate of potash, and one grain of phosphorus; put them into a mortar and rub them together: violent detonations will be produced. In this experiment, the materials are sometimes thrown out of the mortar: it is therefore advisable to protect the hand with a glove, and keep the face out of the way.

5. About half fill an oil flask with water; put in two or three grains of phosphorus and let the water boil. If this is done in a dark place, balls and jets of fire will be seen shooting about on the surface, affording a very curious spectacle.

135. Phosphorus combines with oxygen in two proportions, forming the *phosphorus* and *phosphoric* acids. (See acids.)

It also unites with hydrogen, forming phosphuretted hydrogen.



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Exp. 1. Make a solution of pure potash in water, with which fill a small retort. Put into it a few grains of phosphorus and make the solution boil. Bubbles of phosphuretted hydrogen will be extricated and will take fire as they come in contact with the air. In making this experiment, care must be taken to fill the retort entirely full of the liquid, otherwise the gas will explode, as it reaches the air in the retort. The mouth of the retort must be dipped in a hot solution of the same liquid. The most convenient way of making the experiment, is to cut a piece of wood in a triangular shape, as in fig. 28; on which the retort is to be fastened, while the beak is immersed in the hot solution, and the heat of the lamp is applied at the proper place.

2. Pour about two ounces of water into a thin glass vessel, and put it into two drams of granulated zinc, and ten grains of phosphorus, cut into small pieces, then add two thirds of an ounce of strong sulphuric acid. This affords a very amusing experiment. Bubbles of phosphuretted hydrogen cover the surface of the water, taking fire as fast as they reach the air.

136. Phosphorus combines with the fixed alkalies and earths, forming a class of compounds called *phosphurets.*

Obs. Among these compounds the *phosphuret of lime*, possesses the curious property of giving out phosphuretted hydrogen whenever it is thrown into water.

Exp. To prepare phosphuret of lime, take a glass tube about 12 inches long and half an inch in diameter, stopped at one end. Put first into the tube about a dram of phosphorus, and let it occupy the end that is closed. Then hold the tube horizontally and push into it with a wire, pieces of fresh burned quick lime, about the size of split peas, until it is nearly full, taking care that the lime does not reach the phosphorus by an inch or two; then stop the mouth of the tube loosely, to prevent the free access of air.

Next heat the part of the tube red hot where the lime is, by means of a chafing dish of charcoal, taking care to keep the phosphorus cool; when the lime is red hot, bring a hot iron, or lamp, under the phosphorus, so as to sublime it and bring the vapour in contact with the red hot lime. The lime and phosphorus will unite and form a compound of a reddish brown colour. This is phosphuret of lime.

If a few grains of it be thrown into a glass of water, bubbles of phosphuretted hydrogen are soon extricated from it, which take fire, with a slight explosion, as fast as they reach the surface, affording, except the smell, a very beautiful experiment.

Obs. It will be observed that water was used in all the above experiments, where phosphuretted hydrogen was obtained. It is by its decomposition that the hydrogen is extricated. In the first experiment, the oxygen of the water uniting with the phosphorus, forms phosphoric acid, which is absorbed by the alkali, while the hydrogen being set free, unites with a quantity of the phosphorus, forming phosphuretted hydrogen.

In the next experiment, the hydrogen is furnished by the decomposition of the water, by the zinc and sulphuric acid.

The phosphuret of lime decomposes the water by uniting with its oxygen, while the hydrogen unites to a quantity of phosphorus, as above.

137. Phosphorus readily combines with sulphur, forming a *phosphuret* of sulphur.

138. In the natural state, phosphorus is found combined with lime in the form of an acid, forming phosphate of lime, which is the composition of bones.

OF SULPHUR.

139. Sulphur is a well known substance of a yellow colour, without much taste and without smell, unless it is heated or rubbed. So far as is known, it is a simple body. It exists in nature in great abundance, being found in the animal, vegetable, and mineral kingdoms, but chiefly in the latter.

Obs. The sulphur of commerce is chiefly dug out of the earth in volcanic countries, or in the craters of extinct volcanoes. It is deposited in these places by *sublimation*, being brought up by the heat from the depths below, where it existed in combination with metallic substances. It is also obtained, of an inferior quality, during the process of refining copper ore.

140. When sulphur is heated to a little above the temperature of boiling water, it melts and becomes completely fluid. But it is a singular fact, that if the heat be raised much above this, it again becomes solid, and becomes fluid again as the temperature is reduced.

If after it is melted, it is suffered to cool, it shoots into crystals.

141. When sulphur is in complete fusion, if it is poured into water it becomes soft and tenacious like wax.

Obs. In this state it is made use of to take impressions from medals and engraved stones, and as it soon becomes hard, it will retain the impression for any length of time.

142. When sulphur is exposed to a heat of about 300 degrees, it *sublimes*, or is converted into vapour.

Obs. In this state it is called *flowers* of sulphur, and differs from *brimstone* only in being more pure, and in a state of minute division.

143. Sulphur combines with the earths, alkalies, and metals, and forms a class of compounds called *sulphurets*.

144. It unites to oxygen in two proportions and forms two acids, the *sulphurous* and *sulphuric*. (See acids.)

145. It unites with hydrogen, forming *sulphuretted hydrogen*. This substance is extricated from animal substances during their decomposition, and is chiefly the cause of the disagreeable smell.

OF CARBON.

146. Carbon is a constituent of all vegetable and animal substances. When perfectly pure and crystalized, it constitutes the most costly of all substances, the diamond.

Obs. If carbon could be crystalized by art, the diamond would immediately lose a great part of its value. But as yet this has been effected in the laboratory of nature alone

147. The method of making charcoal is by submitting wood to a red heat, having it covered from the contact of the air.

Example. Expose wood of any kind, stripped of its bark, to a red heat in a close vessel, till vapours cease to issue, and you obtain a black, opake, brittle substance, easily reduced to powder, and without taste or smell. This is charcoal.

Obs. If you pound it and wash away the salts it may contain by diluted muriatic acid, and afterwards, by repeated effusions of cold water, and then dry it at a low red heat, you obtain it sufficiently pure for experiment. Common charcoal, dried in an oven, will do, where great nicety is not required.

148. Charcoal is fixed in the fire, no degree of

heat being able to produce any change on it, so long as the air is excluded.

Obs. When newly made, it will absorb about 90 times its own bulk of ammoniacal gas, and certain, but less quantities, of any other gaseous substance.

149. It attracts from the air a quantity of water, which it strongly retains. The powder of fresh charcoal, is strongly disposed to unite to the odorous particles of bodies and the colouring matter of vegetables : hence it may be employed to correct the bad smell of corrupted water, of oiled silk bags, of ill-conditioned ulcers, and of decayed teeth, when used as a tooth powder : it is employed to deprive vegetable infusions and other substances used in chemistry, of their colour, and for giving mellowness and maturity to newly distilled spirits.

Obs. Its principal use is as fuel, but it always ought to be remembered, that the gas which arises from burning charcoal, is the most insidious and deleterious that can be inhaled.

150. Charcoal, when perfectly freed from saline and earthy matters, may be considered as pure carbon, differing from the diamond only in form and colour.

151. Charcoal has the quality of rendering putrid substances sweet, and preserving animal substances from putrefaction.

Illus. 1. Let putrid water, as from a ditch, be passed through a few inches in depth of pulverized charcoal. It will come through perfectly sweet, and fit to drink.

2. Finely powdered charcoal is of peculiar efficacy as a dentrifice, its particles being sufficiently hard to remove the concretions from the teeth, without hurting the enamel, while at the same time it destroys the fetor arising from a carious tooth.

3. If meat that is a little tainted be rubbed with fine charcoal, it becomes sweet. Fresh meat may be preserved for a considerable time, if surrounded with pulverized charcoal.

For all the above purposes, it is understood that the charcoal is to be fresh prepared, finely pulverized, and perfectly dry.

152. Neither air nor moisture affect charcoal at ordinary temperatures.

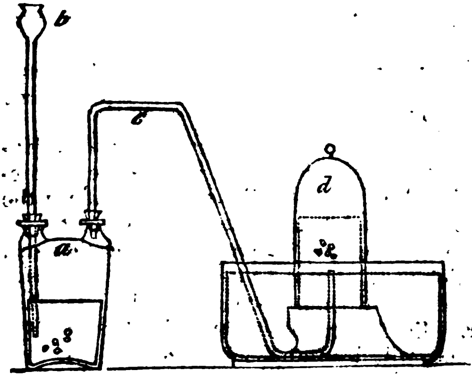
Illus. It is stated by Mr. Watson, that the beams of the theatre at Herculaleum, which were converted into charcoal above 1700 years ago, are still as entire as if this event had happened only yesterday. It is also said, that there still exists charcoal made of corn in the days of Cæsar, which is in so perfect a state, that the grains of wheat can be distinguished from those of rye.

153. Carbon unites to several substances, forming a class of compounds called *carburets.*

Illus. The substance used for pencils, and improperly called *black lead*, is a carburet of iron, and contains about ten parts of carbon to one of iron. The name black lead was given it long before its real composition was known. *Steel* is a carburet of iron, or a compound of iron and diamond; hence its hardness. The conversion of iron into steel depends on a quantity of carbon which it absorbs from the charcoal when it is heated. *Case hardening* is the superficial conversion of the surface of iron into steel, by heating it in contact with animal carbon in close vessels. Bar iron is converted into steel in the same way; only that powdered charcoal is the substance in which it is imbedded.

154. Carbon is the base of carbonic acid.

Illus. When a piece of charcoal is burned, the oxygen of the atmosphere unites to the carbon, forming carbonic acid gas. It is the same kind of gas which is formed during the fermentation of liquors, as beer, &c. and which give them their agreeable smartness and pungency.



155. Carbonic acid may be obtained for the purpose of experiment, by extricating it from its natural combination with lime, or marble.

Exp. For this purpose, introduce pure white marble, in small fragments, into the two-necked bottle *a;* then pour down the funnel *b* some muriatic or sulphuric acid, diluted with five or six parts of water. Effervesence will immediately ensue, and the gas, passing through the bent tube *c* will pass into the jar *d*, which is inverted in a water bath.

156. This gas is nearly twice as heavy, bulk for bulk, as atmospheric air. It will neither support flame nor animal life.

Illus. 1. Counterpoise a large funnel of paper in a pair of scales, and pour carbonic acid into it from a vessel as you would do water, and the descent of the balance will show that this gas is heavier than atmospheric air.

2. Place a short piece of taper or candle burning, on the bottom of a deep tumbler, and pour into the tumbler some carbonic acid, as you would water. The flame will instantly be extinguished.

3. If an animal be confined in this gas it dies in a few minutes.

Obs. When air is so foul as to extinguish a burning body, no animal can live in it; hence, when there is reason to suspect the presence of carbonic acid in wells, or other places, a light ought to be introduced before any person ventures. If the light is extinguished, a few buckets of lime water thrown down will absorb the carbonic acid. Such precaution would frequently save the lives of persons, and ought always to be adopted, where there is the least probability that foul air might exist.

157. Carbonic acid combines with earths, alkalies, and metallic oxides, and forms a class of compounds called *carbonates*.

Illus. Among these compounds, carbonate of lime is the most extensive and important. Limestone, marble, and chalk, are of this kind; they are composed of lime, united to carbonic acid. Their mildness to the touch and taste, depends on this union, for wherever this is driven off, as is the case in the preparation of quicklime, there remains a caustic, acid substance.

158. Caustic lime absorbs carbonic acid, and forms with it *carbonate of lime*.

Illus. Prepare some lime water, by pouring hot water on a lump of unslacked quicklime. From a bladder, furnished with a pipe and filled with carbonic acid, force some of it through a vessel of lime water. The water will instantly become turbid, and if suffered to stand, will deposite a white powder. If the water be evaporated and this powder obtained and examined, it will be found to effervesce with acids, and to have all the other properties of chalk.

159. Carbonic acid is formed during the process of respiration.

Exp. By means of a tube blow some air from the lungs into a vessel of lime water. It will become turbid, and if suffered to stand will deposite carbonate of lime.

160. Carbonic acid is absorbed by growing plants; the carbon being retained to form the bulk of the plant, while the oxygen is again emitted.

Illus. It is found, that if a sprig of mint or any other vigorous plant, be confined in a mixture of atmospheric air and carbonic acid, the acid disappears, and is replaced by the same quantity of oxygen gas. Thus, then, the plant absorbs the gas, retains the solid carbon and returns the oxygen. Plants growing in the open air, obtain their carbon from the air of the atmosphere which always contains a proportion of carbonic acid.

161. Carbonic acid is formed during the fermentation of beer and other substances.

Illus. It is this gas which gives the sprightly taste to beer, porter, &c. It is generated by the fermentative process, and frequently in such quantities as to burst bottles and casks.

OF THE METALS.

162. The metals are the most numerous class of undecomposed bodies. They are distinguished by peculiar properties.

163. They possess a peculiar lustre, which continues in the streak, and in the smallest fragments.

164. They are fusible by heat, and in fusion retain their lustre and opacity.

Obs. All the metals are fusible at certain degrees of heat, each having its fusible point, which differs from that of the rest.

165. All the metals except *selenium* are excellent conductors of electricity.

166. Many of them may be extended under the hammer, and are called *malleable;* or under the

rolling press, and are called *laminable* ; or may be drawn into wire, and are called *ductile.* Others are neither to be drawn under the hammer, nor extended by pressure, but may be ground to powder in a mortar ; these are called *brittle* metals.

167. The metals are capable of combining with each other, when melted, in any proportion ; such compounds are called *alloys.*

Obs. The closeness of their texture, their ductility and malleability, and the power they have to reflect light when polished, fit them for being converted into various utensils, both for the purposes of common life and the different arts.

168. The metals, with few exceptions, are the heaviest of all bodies.

Obs. The newly discovered metals *potassium* and *sodium,* swim on water. The lightest among the other metals is tin, which bulk for bulk, is about seven times heavier than water. Hammered platina is twenty-three times heavier than water.

169. The metals differ in their degrees of brilliancy, colour, density, hardness, elasticity, ductility, tenacity, conductibility for caloric and electricity, dilatibility, fusibility, stability, odour, and taste.

Obs. None of the metals, except gold, transmit light. This, when hammered so thin as to take twenty-eight thousand layers to make an inch in thickness, if held between the eye and the light transmits the green rays.

170. The extensible metals, as gold, silver, &c. in whatever manner their surfaces are increased, if this be done with rapidity, grow hot, and crumble under the hammer or press, and finally refuse to be extended any further. It then becomes necessary to submit them to a red heat, when they again recover their malleability. This process is called *annealing*, and none of the metals can be extended to any considerable degree without being frequently heated.

171. All metals are converted into a fluid state by a sufficient addition of caloric.

Illus. The degrees of heat at which metals take the fluid state, are extremely different. Platina is not to be melted by the most intense heat of a forge; by the heat of the compound blow-pipe, charged with oxygen and hydrogen, or by the influence of a powerful galvanic battery, this metal is fused, and takes the liquid form. On the contrary, mercury is in a state of fusion under all common temperatures, and only takes the solid form when it is exposed to a temperature as low as about 40 degrees below the zero of Fahrenheit.

172. The metals, except gold, platina, and silver, undergo a singular change, on exposure to the air and moisture, or to air and heat. They lose their tenacity, and crumble into powder; and at the same time lose also their metallic splendour, but increase in weight. In this state they are called *oxides*.

Obs. This increase of weight and loss of metallic splendour, does not occur when the metal is kept in a *vacuum*, but is found to arise from the oxygen of the air or water, or from both, which unites with the metal, and produces the change in question. Thus iron, when exposed to the open air, and to moisture, spontaneously absorbs oxygen, and is converted into a brown friable matter, called *rust*. This is an *oxide* of iron.

173. Many of the metals have so strong an attachment to oxygen, as to part with it with extreme difficulty, being always united with it in the natural state.

Illus. Manganese is always found in the state of an oxide, and it is only by some of the most powerful agents, that this can be extricated so as to present the metal pure and in its metallic state. This is the case with several other metals.

174. Some of the metals are oxidized with difficulty, but they all unite with oxygen at sufficient degrees of heat. Hence the metals are all of them combustible bodies.

Example 1. Gold, platina, and silver, are capable of being burned, and converted into oxides, by being submitted to the action of the compound blow-pipe, or the galvanic battery.

2. Copper becomes oxidated by being made red hot, and exposed to the atmosphere in that state.

3. Coiled iron wire, when heated for some time to redness in the bowl of a tobacco pipe, loses its metallic splendour, and crumbles into rust, or oxide of iron.

4. Antimony, being exposed to red heat, on an iron plate, and a stream of oxygen gas pressed from a tube attached to a bag containing it, upon its surface, becomes converted, with a beautiful appearance, into oxide of antimony.

5. Zinc, exposed to a red heat in a crucible, is first melted, then converted into an oxide, and finally the oxide sublimes, or rises in the form of vapour, and attaches itself to the sides of the crucible, in the form of a beautiful white powder.

175. Metals are not soluble in acids in their metallic states, but when first combined with oxygen, they are dissolved in acids with great facility.

Illus. Gold will not dissolve in nitric acid, because this does not part with its oxygen with sufficient facility to form an oxide of the metal. But if a quantity of muriatic acid be added to the nitric, the gold instantly begins to dissolve, or enter into solution, because the muriatic acid imparts its oxygen to the gold, with which it forms an oxide, and which is instantly dissolved by the nitric acid.

2. If a piece of zinc be thrown into some strong sulphuric acid, it will remain undissolved; but if three or four parts of water be added, the metal is attacked with great violence, and soon dissolved. In this case the water furnishes the oxygen, by which the zinc is oxidized, and it is then dissolved by the acid.

176. The weight of a metal is increased by being converted into an oxide.

Illus. If 100 pounds by weight of lead be melted in the open air, and kept in fusion, it gradually absorbs oxygen and is converted into *red lead* or *minium*. During this process, the lead acquires an accession to its weight of about 10 pounds to the 100, which is the weight of the oxygen, the metal had absorbed to convert it into an oxide.

2. Weigh a coil of iron wire accurately, and then burn it in oxygen gas, in the way formerly described. Then weigh the oxide formed by the burning, and it will be found to weigh more than the wire did. When the iron and gas are both weighed, the gas is found to have lost exactly what is gained by the iron.

177. Metals, after being converted to oxides,

may again be *revived*, or brought back to their metallic state. This process is termed *reduction.*

Illus. This depends on an operation opposite to that of oxidation, and is effected by the addition of substances which have a greater attraction for oxygen than the metals have. Thus carbon has a stronger attraction for oxygen than any of the metals. Mix therefore the metallic oxide to be reduced, say the red oxide of lead, with charcoal powder in a crucible, and on exposing them to a red heat the metal will be *reduced,* and appear in its metallic form.

Obs. In the reduction of the oxides of metals by charcoal, there is a quantity of carbonic acid gas formed equal in weight to what is lost by the oxide and the charcoal ; because the materials of which the carbonic acid is formed are furnished by the two substances, the oxygen by the lead, and the carbon by the charcoal.

178. Some of the metals have so feeble an attraction for oxygen, that when they are converted into oxides, the action of heat alone is sufficient to drive off the oxygen and reduce them to the metallic state.

Illus. Mercury, by the long and patient application of a moderate heat, is changed to the state of a red oxide. If this red oxide be exposed to a higher degree of heat, the oxygen abandons it and flies off in the form of oxygen gas, while the oxide is reduced to a metal.

It is on this principle that oxygen gas is obtained from black oxide of manganese, which being exposed to a red heat, in a gun-barrel or iron retort, yields it in abundance.

179. The metals unite with sulphur, phosphorus, and carbon, forming compounds called *sulphurets, phosphurets,* and *carburets.*

180. Of all the inflammable bases, sulphur appears to have the strongest affinity for metals, and its combinations with some of them are attended with remarkable phenomena.

Exp. Introduce into a Florence flask, three parts of iron filings or copper filings, and one part of flowers of sulphur mixed together. Then cork up the flask and place it over a lamp, so as to heat it slowly. As soon as any redness appears, remove the flask from the fire; incandescence will go on, the mixture glowing with red heat, which in the dark exhibits a very beautiful appearance.

Obs. As this experiment can be made without the presence of oxygen gas, it was formerly considered an objection to the doctrine, that oxygen is the sole supporter of combustion. But the experiment can be explained on the doctrine of latent heat; for when the vessel is broken, it is found that the two bodies have united and formed a solid compound, viz: a sulphuret of iron or copper. The latent heat, therefore, which the two substances contained, was given out in consequence of their passage into a more solid form.

181. When a metal enters into solution with an acid, a compound is formed, which differs entirely from either of these two substances. This compound is called a *metallic salt.*

Obs. When a metal enters into solution with an acid, the acid remains transparent as before. This circumstance serves to distinguish chemical solution from mechanical mixture, which is always turbid.

Exp. Pour concentrated nitric acid on some granulated zinc, taking care not to respire the vapour. The solution will be transparent.

Obs. As the metal dissolves, red fumes are emitted in abundance; these are *nitrous acid gas.* The acid is decomposed and the metal is oxidated at the expense of that portion of oxygen which constituted *nitric acid;* the consequence is, that the loss of this portion of oxygen converts the nitric acid into nitrous acid gas, which flies off as fast as it is produced.

182. The metallic salts are much employed in the arts and in medicine.

Illus. 1. Sulphate of iron, or what is called *copperas*, and sulphate of copper called *blue vitriol*, are of indispensable use in the art of dyeing.

2. Calomel, tartarized antimony, corrosive sublimate, white vitriol, sugar of lead, and many other metallic salts are used in medicine

Obs. The metals while in the metallic state are insoluble in the stomach, and consequently are entirely inert as medicines. Thus mercury or silver may be swallowed, without producing any other than mechanical action on the stomach; but if these are dissolved in nitric acid, forming *nitrates* of mercury and silver, they become powerful remedies, and if taken in over doses, strong poisons.

183. The oxides of metals readily unite by fusion with glass, and give to it all the different tinges, by which it is made to resemble gems and precious stones.

Illus. Oxide of gold, when fused with glass gives it the colour of ruby red ; oxide of copper gives it a lively green ; oxide of silver the colour of topaz ; oxide of manganese a purple ; arsenic an opake white ; cobalt a lively blue : and the several oxides of iron under different circumstances, will give all or any of these colours, but less vividly.

Obs. Flint glass contains lead in a considerable quantity ; it renders it soft and more easy to cut, and less apt to break. Queen's ware is glazed by litharge. The common glaze for stone ware is galena (sulphuret of lead) or common salt and black oxide of manganese.

184. When two or more metals are fused together, they enter into chemical combination and form an *alloy*. These compounds differ greatly from the original metals of which they are formed. In general the specific gravity of the alloy is greater than that of either of the metals, and it is also more easily fusible.

Illus. 1. Two bullets of copper, melted with two of tin of equal bulk, form about three bullets of the same size ; but these three weigh as much as the four did in a separate state.

Obs. This may be accounted for, by supposing that the particles of the two metals enter into a closer union with each other when combined, than those of either did when in a separate state.

2. If eight parts of bismuth, five of lead, and three of tin be melted together, they form an alloy which fuses in boiling water.

Obs. This affords a very striking instance of the changes which the metals undergo by a chemical union with each other. In a separate state bismuth fuses at 460 degrees, lead at 450 degrees, and tin at 410 degrees ; but when combined the alloy fuses at 212 degrees.

Exp. Make a tea spoon of the above alloy, and let a person who knows nothing of the matter put it to the common use, Whenever it is dipped into a cup of hot tea, the bowl will be melted off.

185. Alloys are used for *soldering.*

Illus. The solder used for gold work is a mixture of gold and silver, and for silver, a mixture of silver and copper. Plumber's solder is made of two parts of lead and one of tin fused together.

Obs. While other metals are joined by soldering, iron and platina are joined by *welding.*

186. Compounds of metals are observed to oxidize more readily than the metals separately. This is also the case whenever two metals touch each other.

Illus. The copper sheathing of vessels, is soon oxidated where the iron nails are driven through it. If quicksilver is rubbed on tin, the brilliancy of both is soon destroyed.

Obs. These effects depend on the galvanic action which the metals have on each other.

187. Nature rarely presents any of the metals in a state of purity; gold, platina, and silver excepted. They are generally found in the state of *ores*, being chemically combined with sulphur, phosphorus, carbon, acids, earths, or oxygen.

Obs. Metals in the state of ores are said to be *mineralized* with the substance with which they are combined. Thus lead is commonly found combined with sulphur, the lead then is mineralized with sulphur.

188. The methods adopted for extracting the metals from their ores, depend on the nature of the mineralizing substances, and the kind of ore to be operated on.

Illus. Ores of iron, lead, and zinc, and some species of copper require nothing but an intense heat in a charcoal fire. Mercury when combined with sulphur, requires to be distilled with filings of iron; the iron combining with the sulphur forms a sulphuret of iron, while the mercury being disengaged, is easily obtained.

189. Some of the metals are *malleable*, that is, may be drawn under the hammer. Others are *brittle* and may be easily reduced to a powder in a mortar. Some are easily fused, others are melted

with great difficulty. Some are called *refractory*, because they have never been entirely deprived of their oxygen.

Obs. The above properties make it convenient to threw the metals into four distinct classes

Illus. Class 1st, comprehends the malleable metals, which are fourteen in number, viz. gold, platinum, silver, mercury, palladium, rhodium, iridium, osmium, copper, iron, nickel, tin, lead, and zinc.

Obs. Mercury becomes solid and malleable at 40 degrees below zero.

Class 2d, includes such metals as are *brittle and easily* fused, viz. bismuth, antimony, tellurium, selenium, and arsenic.

Class 3d, includes such metals as are *brittle and difficultly* fused. These are cobalt, manganese, chrome, molybdenum, uranium, and tungsten.

Class 4th, includes the *refractory* metals, so called, because they have never yet been exhibited in a perfectly metallic form, but always in combination with more or less oxygen. These are titanium, columbium, and cerium.

CLASS I.

MALLEABLE METALS.

190. **Gold** is a metal of a yellow colour, of the specific gravity of 19, being nineteen times heavier than water, bulk for bulk. It is soft, very rough, ductile, and malleable.

Obs. The limits of the ductility and malleability of gold are unknown. It however has these properties to a greater degree than any other known metal. By the weight and measure of the best wrought gold leaf, it is found that one grain is made to cover fifty-six and three-quarter square inches; from the specific gravity of the metal, together with this admeasurement, it follows that the leaf itself is only the two hundred and eighty thousandth part of an inch in thickness. This however is not the limit to which gold may be extended. The wire which is used by the lace makers, is drawn from an ingot of silver previously gilded.

In this way, from the known diameter of the wire, or breadth when flattened, and its length, together with the quantity of gold used, it is found by computation that this covering of gold is only one 12th part of the thickness of gold leaf, though it is still so perfect as to exhibit no cracks when viewed by a microscope.

191. Gold is melted at a moderate heat, and when fluid is of a green colour. It remains fixed in the fire, the powerful heat of a glass furnace producing no other effect than to keep it in fusion.

Obs. Other metals, platina excepted, are soon oxidated, or turned into vapour at high degrees of heat. Gold will remain in fusion for any length of time without undergoing any change. It may however be brought to the state of an oxide by means of a powerful galvanic battery, and gold leaf burns, when introduced into chlorine gas.

192. Gold is not dissolved by the nitric, sulphuric, or muriatic acids, separately.

Obs. The proper solvent of gold is a mixture of two parts of nitric, and one of muriatic acid. This mixture is called *aqua regia.*

Exp. Put nitric acid into one vessel and muriatic acid into another, and throw a little gold leaf into each; no effect will be produced; but if the two acids are mixed, the gold is instantly acted on and is soon dissolved.

198. The solution of gold is decomposed by certain combustible bodies, which attract the oxygen from the gold and restores it to its metallic state.

Exp. 1. Into a dilute solution of nitro-muriate of gold, contained in a glass jar, put a long narrow slip of charcoal, and expose the whole to the direct light of the sun. The gold will be revived and will cover the charcoal with a coat of the metal, exhibiting a beautiful appearance.

Obs. By the assistance of light, charcoal absorbs the oxygen from the oxide of gold, in consequence of which the metal is deposited.

Exp. 2. Moisten a piece of white taffeta ribbon with a dilute solution of gold, and expose it while moist to a current of hydrogen gas, from a tube and bladder. The gold will be reduced, and the ribbon will be gilded with the metal. By means of a camel's hair pencil the gold may be so applied as to exhibit regular figures.

194. Gold is precipitated from its solvent by

ether, but the oxide is instantly re-dissolved by the ether, and forms an etherial solution of gold.

Obs. The etherial solution of gold may be applied to the gilding of steel scissors, lancets, and other instruments, which it protects from rust, at a very small expense.

Exp. Into a given quantity of nitro-muriatic solution of gold, pour twice as much sulphuric ether, shake them together, and let the vessel stand for two or three minutes; then pour off into another vessel about one third of the mixture. This will be an etherial solution of gold. To gild with it, make a polished steel instrument perfectly clean, and dip it into the solution, then plunge it into water, to wash off any acid there might be in the ether. The instrument will be covered with a coat of gold which may be burnished.

195. **Platina** is a white metal resembling silver in colour. It is the heaviest of all known substances, its specific gravity, when hammered, being 23.

Obs. Platina comes chiefly from Santa Fe, in South America, and consists of small grains or scales, of a colour somewhat lighter than iron, and extremely heavy. In this state it is adulterated by several other metals, and requires to be purified before it is malleable.

196. Pure platina is extremely difficult of fusion, but when exposed to a white heat it softens so as to be welded like iron.

Obs. Platina may be melted by exposing it in small quantities to Hare's blow-pipe, charged with oxygen and hydrogen gases.

197. Platina is not oxidated by exposure to air, or to the continued heat of a furnace; neither is it acted upon by the most concentrated simple acids.

Obs. The proper solvent of this metal is aqua regia, composed of one part of the nitric, and three of the muriatic acid. The colour of the fluid becomes first yellow, and as the solution goes on, it becomes deep reddish brown. This solution is very corrosive and tinges the skin of a blackish brown colour.

198. Platina combines with most of the other metals by fusion, and forms alloys possessing various properties.

Illus. It renders silver more hard, but its colour more dull.

Copper, when alloyed with from 1-6th to 1-25th part of it, is rendered of a golden colour; is much less apt to rust, and receives a finer polish.

With iron it is said to form a compound much esteemed by the Spaniards, for the purpose of making gun-barrels, which are stronger, and much less apt to rust than iron alone.

199. Platina is so ductile that it may be drawn into wire not exceeding the three thousandth part of an inch in diameter.

200. From its infusibility and the difficulty with which it is oxidated, this metal is of great value in the arts, and for making various chemical and philosophical instruments.

Obs. Platina is a remarkably slow conductor of caloric. Thus when equal pieces of silver and platina are coated with wax, and heated at one end, the wax on the silver will be melted 3 1-2 inches in the same time that only one inch is melted on the platina. This property of conducting heat slowly has been applied to a very curious and useful purpose. If a coil of platina wire surrounding a cotton wick immersed in alcohol, be made red hot, the evaporation and combustion of the alcohol keeps it in this state. Thus we have a coil of wire constantly red hot without flame, and from which, by means of a match, a light may be obtained at any moment.

201. SILVER is a metal which admits of a lustre inferior only to that of polished steel. The specific gravity of hammered silver is about 11, being about half that of platina. In malleability, ductility, and tenacity, it exceeds all the metals except gold. It is fused in the heat of a common furnace, and if the heat be raised to the highest pitch, it is volatized, or turned into vapour. By slow cooling it may be obtained in regular crystals.

Obs. Silver may be melted and kept in fusion without being oxidized; it is however converted to an oxide by a powerful galvanic or electric discharge, and by being for a long time exposed to heat with access of air, it is at length converted into an olive coloured glass.

202. The proper solvent of silver is nitric acid, of which it will dissolve more than half its weight. It must first be diluted with water.

Exp. Throw some thin pieces of silver into nitric acid; it instantly begins to dissolve with effervesence, sending forth copious quantities of nitrous gas. The solution is at first blue, but if the silver is pure the colour disappears, and the solution becomes transparent. If coin silver be used the solution is green, because this is always more or less adulterated with copper.

Obs. 1. This solution is extremely caustic and will tinge the skin, nails, hair, or other animal matter of an indelible black colour.

2. When the solution is concentrated by evaporation and then suffered to stand for a few hours in a cool place, crystals of nitrate of silver are formed.

3. These crystals, when fused and cast into cylindrical moulds, form the *lunar caustic* sold by apothecaries. This is an extremely caustic substance, and will in a few moments destroy flesh or skin when suffered to touch it.

4. Lunar caustic, when dissolved in water, forms the indelible ink, sold for the purpose of marking linen and cotton cloths. It also forms the article sold for colouring hair.

203. Silver may be precipitated from its solution by other metals, and by the *alkalies* or the *earths*.

Exp. 1. Dissolve some nitrate of silver in pure water, and dip into it a clean and polished slip of copper. The copper will be covered with a coat of silver.

2. *Diana's silver tree*, is made by precipitating nitrate of silver from its solution by means of mercury. Mix together six parts of a solution of nitrate of silver, and four of a solution of nitrate of mercury, both completely saturated. Add a small quantity of distilled water; and put the mixture into a glass decanter, containing six parts of an amalgam made with seven parts of mercury and one of silver. In the course of some hours there appears small shining scales of reduced silver, which shoot out in the form of a tree, producing a very beautiful appearance.

3. Prepare some silvering powder as follows. Precipitate silver, from its solution in nitric acid, by dropping into it plates of copper. Take 20 grains of this powder and mix with it two drachms of cream of tartar, the same quantity of common salt, and a half a drachm of alum. These articles must be finely pulverized and well mixed together. If some of this powder be moistened and rubbed on a clean polished surface of brass or copper, the silver will be precipitated, and the surface will be covered with it. In this way the silvering of candlesticks, or other articles, where it is worn off, may be replaced.

204. Silver may be precipitated on ivory, and revived by the action of solar light.

Exp. Make a dilute solution of lunar caustic in pure water. Immerse in this a slip of polished ivory until it acquires a bright yellow colour. Then take it out and expose it to the direct rays of the sun immersed in a glass of pure water. It will turn black by the action of the light, but if it be gently rubbed, the surface will be changed to a bright metallic one, resembling a bar of silver.

Obs. This effect is owing to the action of solar light which decomposes the nitrate of silver by depriving it of its oxygen.

205. A very useful solvent of silver is formed by dissolving one part of nitre in about eight parts of concentrated sulphuric acid.

Obs. This solvent, when heated somewhat less than boiling water, will dissolve silver, without touching gold, copper, lead, or iron: hence it may be used to extract the silver from old plated goods.

206. MERCURY, or quicksilver, is the only metal that retains the fluid form, at the ordinary temperature of the atmosphere. Its specific gravity is 14.

Obs. When the temperature of mercury is reduced to 40 degrees below zero, it assumes a solid form and becomes a malleable metal. Mercury is not oxidized when pure, at the ordinary temperature of the atmosphere. There are several methods, however, by which it may be brought to combine with oxygen.

Illus. Mercury may be oxidized by long continued agitation in a bottle half filled with air, and is converted into a black powder called *ethiops* mineral.

Another oxide is obtained by exposing the metal for several days to nearly a boiling temperature, the air being admitted to act on its surface. This oxide is red.

207. Mercury easily combines with gold, silver, lead, tin, bismuth, and zinc; more difficultly with copper, arsenic, and antimony, and scarcely at all with platina, or iron.

Obs. These metallic mixtures are called *amalgams.*

Illus. The gold-beaters make use of mercury as a means of obtaining the small particles of gold contained in the sweepings of the shop, &c. The sweepings being put into a close vessel, mercury is poured in with them, and then the vessel being agitated, the mercury selects out the particles of gold and forms with them an amalgam. The amalgam is then put into a buckskin bag and pressed ; this forces the mercury through the pores of the leather, while the gold is retained.

208. Mercury is applied to a variety of uses in the arts, and is much employed in medicine.

Illus. 1. *Vermillion* is prepared by first uniting by fusion, mercury and sulphur, and forming a sulphuret of mercury. This compound is then sublimed by heat, and then pulverized. The powder is vermillion.

2. The *silvering* on looking glasses is an amalgam of tin. A sheet of tin foil is laid smooth on a slab of marble, and on the tin foil mercury is poured until it is about the eighth of an inch deep, the attraction of the tin for the mercury keeping it from running off. When the mercury is spread equally over the tin, a plate of glass is run, or slid on. This is so managed by partly immersing the end of the plate in the edge of the mercury, and pushing it forward, as entirely to exclude the air from between the plate and metal. Weights are then laid on the plate to press out the mercury which has not amalgamated with the tin. At the end of 24 or 36 hours, the amalgam is found adhering to the glass in the manner we see it.

3. Mercury is the substance, with which barometer and thermometer tubes are filled.

4. As a medicine, mercury is employed under a great variety of forms. Among these that of *calomel* is the most common. This is a *sub muriate* of mercury. It is prepared by grinding in a mortar two parts of muriate of mercury, or what is called *corrosive sublimate*, with one part of crude mercury ; it is then sublimed several times, and then repeatedly washed to dissolve and wash away any remains of the muriate it might contain. It is then fit for use.

209. **Rhodium** is a metal which Dr. Wollaston discovered in his analysis of platina. It has been obtained only in small quantities, and is of no use in the arts, or otherwise.

210. **Palladium** is also separated from crude platina, and is found native, among the grains of that metal. Its colour is white. It is ductile and malleable. Specific gravity 10, or 11. Sulphuric acid boiled with it, acquires a beautiful blue, and dissolves a portion of the metal.

Obs. Palladium combines with other metals, and like platina destroys the colour of gold, rendering it even in very small quantities nearly white. It oxidizes with difficulty, and when alloyed with gold, produces a hard compound, which has been applied to some particular uses in the construction of philosophical instruments.

211. IRIDIUM is also extracted from the ore of platina. Its colour is white. It is perfectly infusible, except by the influence of an immense galvanic battery. No use has hitherto been made of it. Its specific gravity is 18.

212. OSMIUM is obtained from an alkaline solution of iridium. It is of a dark grey or blue colour. It is infusible. No use is made of it.

213. COPPER is a metal of a beautiful red colour, and admits of a high degree of lustre. Its specific gravity is from 8 to 9. It is malleable, and may be hammered into very thin leaves. It is also ductile, and may be drawn into wire, which has great tenacity. It fuses in the heat of a common forge, and at a high degree of heat is evaporated with visible fumes.

214. Copper is oxidized by air.

Illus. Heat a bar of polished copper and expose it to the air. It will exhibit various shades of colour, or various degrees of oxidizement, according to the degrees of heat.

215. Copper combines with several acids and forms metallic salts of various kinds.

Illus. Sulphuric acid dissolves copper at a boiling heat, and forms sulphate of copper, a salt of a very beautiful blue colour, known by the name of *blue vitriol.* This is a caustic, poisonous substance.

Obs. Sulphate of copper is decomposed by iron.

Exp. Make a solution of sulphate of copper in water, and immerse in it a polished plate of iron; the iron will be covered with a coat of metallic copper.

216. Copper combines readily with nitric acid, and forms with it a green salt, which has the power of inflaming tin.

Exp. Place a drachm or two of nitrate of copper, on a piece of tin foil three or four inches square. Moisten the salt by sprinkling it with water, and instantly fold it up including the salt in several layers of the foil; at the same time press down the edges of the tin so as to exclude the air. In a few minutes the nitrate will begin to act upon the tin; the folds will be burst open, and sparks of fire be emitted, and finally it will inflame.

Obs. In the above experiment, the nitrate of copper is decomposed in consequence of the strong attraction which the tin has for oxygen, and the ease with which this salt parts with it. The oxygen, therefore, combines with the tin with such rapidity as to give out sufficient heat to set it on fire. The red fumes are in consequence of the abstraction of oxygen from the nitric acid of the salt, by which it is converted into nitrous gas.

217. *Verditer* is nitrate of copper precipitated by carbonate of lime. It is of a blue colour and is used as a pigment.

218. *Verdigris* is an accetate of copper. It is prepared by exposing the metal to vapour of vinegar, or the corroding effects of grapes after the wine is pressed out.

219. *Mineral green* is prepared by precipitating copper from its solution in sulphuric acid, by means of caustic potash.

Obs. Sulphate of copper is frequently found in streams of water running through copper mines. In the island of Anglesia, this circumstance is turned to advantageous account by throwing waste iron into the water, on which the copper is precipitated in the metallic form. It is afterwards scraped off and melted for use.

220. Copper combines readily with other metals and affords several compounds which are of great use in the arts of life.

Illus. Copper, with about a fourth of its weight of zinc, forms *brass*, the most useful of all alloys.

Tutenag is a white alloy of copper, zinc, and iron. Copper, with various proportions of zinc, forms *Tombac*, *Dutch Gold*, *Prince Rupert's* metal, *Pinchbeck*, &c.

Obs. Copper vessels for culinary purposes are dangerous; the presence of any acid forming with it a poisonous salt.

One of the best tests of the presence of copper is ammonia; which strikes a beautiful blue colour with its solutions.

221. Iron is the most abundant and useful of all metals. It is found chiefly among primitive rocks; both animal and vegetable substances also contain it. Next to copper, it is the most sonorous among the metals. Its bluish white colour, its elasticity and hardness, we are all acquainted with. Its specific gravity is a little more than 7.

222. It is the toughest of all metals, is less malleable, but more ductile than gold or silver.

Illus. The ductility of iron is such that it may be drawn into a wire not exceeding the size of a human hair. Its tenacity is such, that a wire only 78-1000th of an inch in diameter will support a weight of more than 500 pounds.

223. Iron is sometimes found native, but most of it is dug out of the earth, where it is found mineralized by oxygen or sulphur.

Obs. Iron is reduced at a high temperature from its oxide by charcoal, and when earth is connected with it, by the further addition of lime.

224. At a high temperature iron absorbs oxygen from water.

Illus. Heat a gun barrel red hot and pass water through it in the state of steam. The iron absorbs the oxygen, while the hydrogen passes over in the state of gas.

225. When iron is exposed to the combined action of air and moisture, it absorbs oxygen at common temperatures.

Illus. The common *rust* of iron is an oxide of that metal.

226. Iron combines with acids, and forms compounds of various kinds.

Obs. Among these, the sulphate of iron, called also *green vitriol* or *copperas*, is the most important.

227. When sulphate of iron is mixed with an infusion of galls, we obtain a black solution, which is a new compound of oxide of iron with the gallic acid and tan.

Illus. Writing ink is a *gallate of iron*, made with tincture of galls, and sulphate of iron.

Obs. The black colour of ink is owing to its combination with oxygen.

Illus. The addition of iron filings to ink destroys its colour by obsorbing its oxygen. Characters written with ink after this treatment, are at first illegible, but become black as the iron acquires oxygen from the air. Writing ink newly made is well known to grow more intensely black by exposure to the air; this is on the same principle.

228. Ink is decomposed by alkalies, by acids, and by age. In some instances its colour may be restored by adding the ingredient which is lost.

Illus. 1. The alkalies, as potash, or soda, will destroy the colour of writing; but the colour may be restored by moistening the paper with infusion of galls on a camel's hair pencil.

2. Ink is decomposed by age, partly in consequence of the farther oxidation of the iron, and partly in consequence of the destruction of the gallic acid. Hence ink stains degenerate into iron-moulds, and these last are immediately produced on an inked spot of linen when washed with soap, because the alkali of the soap abstracts the gallic acid, and leaves only an oxide of iron. Hence also the yellowish colour which is produced by dipping linen into a solution of sulphate of iron and called a *copperas colour*, is only a precipitation of the oxide of iron on the cloth.

229. Iron combines with carbon in various proportions.

Obs. 1. Steel is a compound of iron and carbon; the iron absorbs the carbon from the charcoal with which it is heated.

2. *Cast*, or *crude* iron, contains oxygen and carbon. When these are got rid of by the process of refining, *malleable*, or *bar iron* is formed. Iron, however, always contains more or less oxygen and carbon.

3. Cast iron occupies a less space in a fluid, than in a solid form. Hence its fitness for castings. This fact depends on the crystalline form which the iron takes on cooling.

230. NICKEL is perfectly malleable and may be forged when hot, and hammered into plates when cold. Its colour is white, and intermediate between those of silver and tin. It admits of being finely polished, and has a lustre between steel and

platina. Its ductility is such, that it may be drawn into very fine wire. It cannot easily be soldered on account of the oxide which forms on its surface when heated. It is one of the most infusible of the metals. Like iron, it is magnetic.

By long exposure to red heat, it is converted into a dark brown oxide, which is still magnetic. Its specific gravity about 9. At a sufficiently high heat its oxides are reducible without addition; nor is it more tarnished by a strong heat than gold, silver, or platina. It ranks, therefore, among the noble or perfect metals.

231. The principle ore of this metal is a sulphuret. It comes from various parts of Germany, where it is found with cobalt.

Obs. 1. It is a curious circumstance, that nickel has been found alloyed with iron in all the specimens of stones which have fallen from the atmosphere, where these have been analyzed.

2. Nickel is employed in China in making *white copper*, which is a very beautiful compound. It has also been proposed to make use of this metal in combination with steel, for the purpose of making surgical instruments, as such an alloy is not liable to oxidize.

232. **Tin.** The properties of tin must be examined in the state of grain-tin, or block-tin; what is commonly known by the name of tin being nothing more than iron plates with a thin covering of this metal.

233. Tin has a silvery white colour, which is very little altered by exposure to air. It is ductile and very malleable, being easily rolled, or hammered into thin plates. Next to lead it is the softest and least elastic of all elastic metals. Its specific gravity is a little more than 7. It is easily fused, and bends with a peculiar crackling noise.

234. Tin by fusion unites with almost all the other metals. Some of the alloys are of great importance in common life.

Illus. With copper, it forms *bronze*. With antimony, copper and bismuth, it forms *pewter*. With an equal quantity of lead it forms *Plumber's solder*. With mercury it forms the silvering of looking glasses.

235. The plates of tinned iron, which commonly go under the name of tin, and of which tin ware is made, are prepared by dipping plates of iron into melted tin. The tin penetrates the pores of the iron, and adheres to it until it is entirely worn off.

Illus. Dip a clean piece of iron, as a knife blade, into melted tin, and it will come out completely tinned, or covered with the metal.

236. Tin dissolves in the acids, forming solutions of various properties, some of which are of much use in the arts.

Illus. The dyeing of scarlet depends on a solution of tin ni-nitro muriatic acid. Tin is used to precipitate gold from its solution in nitro muriatic acid, by which is formed the *purple powder of Cassius*, much employed in enameling.

237. Lead is of a bluish white colour, but soon loses its lustre when exposed to air. Its specific gravity is about 11, being among the five most ponderous metals.

238. By the joint action of heat and air, lead becomes oxidated, and exhibits different colours according to the proportion of oxygen with which it may have combined.

Illus. If lead be melted, a scum soon forms on its surface; if this is removed, another will quickly succeed; and in this manner the whole of the lead may be converted into the *grey* oxide of lead. If this grey oxide be exposed to a low red heat in a furnace, it will acquire a further dose of oxygen, and be converted into *yellow* oxide, called *massicot*. If the heat be continued, this yellow oxide will be converted into a *red* oxide, called *red lead*.

239. The oxides of lead give out their oxygen on the application of heat, or by being ignited with combustible matter.

Illus. 1. Heat some red lead in a gun barrel, or earthen retort. The oxide will be revived, oxygen gas will be given out. and metallic lead will be found remaining in the vessel..

2. Mix red oxide of lead and charcoal, and ignite the mixture in a crucible; a button of metallic lead will be found at the bottom.

240. Pure water has no action on lead if the air is entirely excluded; but when left in contact with water and exposed to the atmosphere, it soon becomes oxidized and dissolved, especially if agitated. Hence the danger of leaden pipes and vessels for containing water which is intended to be drunk.

241. Sulphuric acid has no action on lead except when concentrated, and at a boiling temperature.

Obs. The insolubility of lead in sulphuric acid, makes it a fit and cheap material for lining the chambers in which this acid is formed. Vessels for boiling down the weak acid are also made of this metal.

242. Lead is soluble in several acids, and forms compounds, some of which are of great importance in the arts of life.

Illus. 1. When two parts of the red oxide of lead *(red lead)* are mixed with one of muriate of soda *(common salt,)* and the mixture is made into a paste with water, the salt is decomposed, and a muriate of lead is formed, which on fusion affords the substance called *mineral,* or *patent yellow.* This is much employed as a paint.

2. When lead is exposed to the fumes of acetic acid, or strong vinegar, there is formed a white crust on its surface, which is called *white lead,* or *ceruse.* This substance is soluble in vinegar, and when dissolved in it and crystalized, it forms the well known salt, acetate, or *sugar of lead.* The method of manufacturing this salt, is first to expose sheets of lead to the fumes of vinegar. This is done by rolling them up and placing them in pots gently heated, with vinegar at the bottom. When the white crust is formed, the sheets are taken out of the pots and immersed in strong vinegar, which dissolves the crust. They are then placed in the pots again, and this is repeated until the sheets are destroyed. The sugar of lead is obtained in crystals, by evaporating the vinegar in which the plates are immersed.

Obs. Lead in its metallic state, is employed for many valuable purposes. Houses are covered with it. It is used for aqueduct pipes, for making cauldrons, for shot, and bullets, &c.

243. Zinc is obtained chiefly from the ore called

calamine, or *lapsis calaminaris*. It is of a brilliant white colour, with a shade of blue. Its specific gravity is about 7, the lightest being the purest metal. By particular treatment zinc is malleable, and may be beaten into leaves. and drawn into wire. The common zinc is neither malleable nor ductile.

244. Zinc is inflammable in common air.

Exp. Heat a crucible to whiteness in a forge and throw into it small pieces of zinc. It will inflame and burn with a beautiful white light.

245. Zinc is soluble in the sulphuric, nitric and muriatic acids.

Obs. Of the salts formed by solution of this metal, that with the sulphuric acid is the most important and best known. This forms sulphate of zinc, or white vitriol, an article much used in medicine.

246. Zinc is capable of furnishing alloys with most of the metals. Of these the most useful is brass, as already mentioned under the article, copper.

CLASS II.

METALS THAT ARE BRITTLE AND EASILY FUSED.

247. Bismuth is of a reddish colour, and is composed of broad brilliant plates, adhering to each other. Its specific gravity is about 10. It breaks under the hammer, and hence cannot be considered as malleable, but it is ductile, and may be drawn into wire. It is one of the most fusible of the metals, and readily forms distinct crystals on cooling.

Obs. When bismuth is kept in fusion at a moderate heat, it becomes covered with an oxide of a brown colour. In a more violent heat it is volatile and may be sublimed in close vessels, but with access of air it emits a blue flame, and its oxide exhales in the form of a yellowish smoke, which is condensed by cold bodies. The matter so condensed is the oxide of bismuth, and the only one with which we are acquainted. This oxide is employed in medicine.

248. The acids dissolve bismuth with effervescence.

249. This metal is capable of being alloyed with most of the metals.

250. Bismuth has the singular property of expanding as it cools; hence, probably, its use in the composition of printing types, as from this expansive property, are obtained the most perfect impressions of the moulds in which the letters are cast.

251. Pearl white is an oxide of this metal. Ladies use it for painting the skin, to which it imparts a beautiful white.

252. Pomatum prepared with oxide of bismuth is said to turn the hair black.

253. Antimony, as it occurs in the shops, is a sulphuret of the metal, and consists of 75 parts of antimony and 25 of sulphur.

254. Pure antimony is a beautiful metal of a silvery white colour, very brittle, and crystalized in the form of plates, or scales. it undergoes little change when exposed to the air, at ordinary temperatures. But when fused, it is easily volatized in white fumes, which is an oxide of the metal.

Obs. The vapour of water, when brought in contact with ignited antimony, is decomposed with so much rapidity as to produce a series of detonations.

255. Antimony is capable of uniting with such proportions of oxygen, as to constitute an acid.

Illus. The white and yellow compounds of oxygen and antimony ought to be arranged among acids rather than among oxides, for each of them combines with salafiable bases. The white oxide is called *antimonious* and the yellow *antimonic* acid.

256. Antimony is applied to various uses in the arts, and is employed in medicine in a variety of forms.

Illus. 1. The most important of its alloys is that which it forms with lead. In the proportion of one part antimony and sixteen lead, it composes the metal for printer's types.

2. When the native sulphuret of this metal, is slowly roasted in a shallow vessel, it loses most of its sulphur, attracts oxygen, and is converted into a grey oxide. When this oxide is melted with a strong heat, it acquires a reddish colour, and runs into a glassy substance, called *glass of antimony*.

3. The well known substance *tartar emetic* is a triple salt, a tartate of potash and antimony and is composed of about 56 parts of tartrate of antimony, 36 tartrate of potash, and 8 of water.

257. Telurium. The colour of this metal is of a tin-white, verging towards lead grey; it has considerable lustre, is very brittle, and breaks with a foliated, or scaly fracture. It is fusible below a read heat and is one of the most volatile of the metals, flying off in fumes at a red heat. When heated in the open air, it burns with a sky blue flame, edged with green. This is the lightest of all the metals, its specific gravity being little more than 6.

Obs. This metal has heretofore been applied to no use in the arts.

258. Selenium, has a grey colour and a very brilliant metallic lustre, and possesses a small, but scarcely perceptible degree of transparency. It softens at 212 deg. Fahrenheit, and completely fuses a few degrees higher. While cooling it has a considerable degree of ductility, and may be kneeded between the fingers and drawn out into fine threads, which have a strong metallic lustre. When heated before the blow-pipe it tinges the flame of a fine azure blue, and exhales so strong a smell of horse radish that a fragment, not exceeding the fiftieth of a grain is suffiient to fill the air of a large apartment.

Obs. 1, Selenium unites with the different metals, and the union is in many instances attended with ignition. When a piece of the compound of this metal and potassium is dropped into an acid, there is extricated a gas of very singular properties. A small bubble of this gas, not exceeding the size of a pea, when drawn into the nostrils, excited inflammation of their membrane, and symptoms of catarrh which did not subside for several days.

2. This metal has been recently discovered. It has heretofore been extracted only from impure sulphur found in Sweden, and only in small quantities. Its uses are unknown.

259. Arsenic. The substance sold by apothecaries and generally known by this name, is a white oxide of the metal.

From this oxide, metallic arsenic may easily be procured.

Exp. Mix five grains of white oxide of arsenic with twenty grains of finely pulverized charcoal ; put the mixture into a glass tube, ten or twelve inches long, and stopped at one end. Apply heat, gradually raised to redness, to the part where the mixture is. The charcoal will deprive the oxide of its oxygen, and the metal will coat the upper part of the tube. It is a white metal, with a lustre not unlike steel.

260. By corking the tube air tight it may be preserved in its metallic state for months or years. It soon tarnishes by exposure to air.

Obs. Metallic arsenic is readily fused and is volatized at 356 degrees. In close vessels it may be collected unchanged ; but when thrown on a red hot iron it burns with a blue flame and a white smoke, at the same time a strong smell of *garlic* is perceived.

261. Metallic arsenic combines with most of the metals, forming alloys.

Exp. Place a small piece of metallic arsenic between two plates of copper, as two cents ; bind the plates together with wire, and submit them barely to a red heat. The inside of the plates will be stained white.

262. The white oxide of arsenic, or *arsenous acid*, is soluble in water.

Illus. According to some experiments, cold water dissolves only a small quantity of this oxide. A thousand grains of water being left in contact with it, dissolved in 24 hours only 2 1-2 grains. But 1000 grains of hot water dissolved about 78 grains of this oxide.

Obs. Every oxide, and every solution of arsenic is strongly poisonous. The pure metal is harmless, but it becomes poisonous in a few moments on exposure to air, and it is probable that the metal swallowed would soon become a poison in the stomach, in consequence of the absorption of the oxygen there.

263. Oxide of arsenic combines with the alkalies to saturation, and hence it fulfils one of the principal functions of an acid. It has therefore been called *arsenous acid*, and its compounds *arseniates*.

Obs. Arsenic is generally known, and sold in the form of white oxide. This is sometimes called *rat's bane*, from the circumstance of its being used for destroying rats. It is used in medicine in the form of *Fowler's solution*. This is an arseniate of potash, and is prepared by adding a certain quantity of the white oxide to a solution of potash in pure water.

CLASS III.

METALS THAT ARE BRITTLE AND DIFFICULTLY FUSED.

264. Cobalt has a greyish white colour, inclining somewhat to red. Its specific gravity is about 7 1-2; it is brittle, and easily reduced to powder. It is infusible except at extremely high degrees of heat.

265. By exposure to the air this metal is tarnished, but not oxidated to any extent.

266. Cobalt is used in the state of an oxide for making colours.

Illus. The blue colour given to China ware, porcelain, glass, enamels, &c. is made by the oxide of this metal

Exp. Take a small piece of cobalt, or of any of its ores, place it on a piece of charcoal with some borax, and apply to it the heat of the blow-pipe. The borax will melt and form a bead of a beautiful blue colour. This is the most simple and certain test of the presence of cobalt, when mixed with other metals.

267. Cobalt, when dissolved in an acid, has the singular property of forming what is called *sympathetic ink*.

Illus. Take one part cobalt, or what is better, the substance called zaffre, and digest it in a moderate heat, with four parts of nitric acid. To this solution add one part muriate of soda, and then add as much water as there was of the acid.

Characters written on paper with this solution are illegible when cold, but when the paper is carried towards the fire they appear of a beautiful blue or green colour. This experiment is rendered more amusing by drawing the trunk and branches of a tree in the ordinary way, and tracing the leaves with the solution of cobalt. In the cold, as in winter, the tree appears leafless, but on moving it near the fire or placing it in the sun in summer, it will suddenly become covered with the most beautiful foilage. The green colour is improved by adding to the nitric acid half its quantity of muriatic acid.

Obs. 1. The cause of this singular change of colour, is difficult to explain. It may perhaps be owing to an additional quantity of oxygen which the cobalt absorbs when heated, and which it parts with again when cold.

Obs. 2. *Zaffre* is an oxide of cobalt, mixed with some vitrifiable earth.

When zaffre is fused, washed, and ground to powder, it forms the article known under the name of *smalts*. This is used for the colouring of paper, linen, glass, &c. It may be purchased of the apothecaries.

268. MANGANESE never occurs in the metallic state ; the black substance, known by that name is an oxide of the metal.

Obs. The pure metal may be obtained from the black oxide by mixing this with powdered pitch, making it into a ball, putting it into a crucible lined with charcoal, and submitting it covered, to the strongest heat that can be raised for one hour.

269. The metal is of a dusky white colour with a specific gravity of 8. On exposing it to the air it soon crumbles into a powder, in consequence of its oxidation, and becomes in succession, grey, violet, brown, and finally, black.

270. The black oxide of Manganese has some properties which make it the subject of amusing experiments.

Illus. It imparts to Borax, when melted with it, a violet colour. When this is effected with the blow-pipe on a piece of charcoal, this violet colour may be destroyed by the interior blue flame, and again reproduced by the exterior red flame, or by a small particle of nitre.

2. When black oxide of manganese and nitre, in equal proportions, are both reduced to a fine powder, and in a state of mixture, are thrown into a red hot crucible, the nitre is decomposed, its oxygen being transferred to the black oxide. This is called the *mineral camelion.*

Exp. Put a piece of this into a glass vessel and pour in a small quantity of water. The solution will be *green;* a little more water will change the colour to *blue;* a further addition changes it to *purple,* and a still larger quantity to a beautiful *deep purple.*

This experiment may be varied by putting equal quantities of this substance into separate glasses and adding to the one hot and to the other cold water. The hot solution has a beautiful green colour and the other a deep purple.

271. Manganese, in its metallic state, combines with most of the metals, and forms alloys, but none of them are distinguished by important properties.

272. The black oxide of manganese is used by chemists for the purpose of obtaining oxygen gas. It is also used in bleaching cotton goods.

Exp. Put some of the black oxide into a flask furnished with a tube, pour on sulphuric acid enough to moisten it, then apply the heat of a lamp. Oxygen gas will be extricated in abundance.

Obs. The sulphuric acid combines with the metal, in consequence of which the oxygen is set free.

273. **Chrome.** This metal is found in an acidified state, combined with lead and iron. The metal may be obtained from either of these ores. It is of a greyish white colour, brittle and infusible.

Obs. The beautiful paint called *chromic yellow* is a chomate of lead. If it is prepared by extracting the chromic acid from chromate of iron, which is then united to oxide of lead.

274. **Molybdenum.** The most common ore of this metal was long mistaken for plumbago, or black lead, which it strongly resembles. They may be distinguished from each other by rubbing

each on a piece of white porcelain, the trace of the molybdena has a greenish tinge, and contains numerous little scales, while the trace of the plumbago is nearly black and consists of grains.

Obs. 1. This metal as well as chrome, is capable of combining with such a quantity of oxygen as to constitute it an acid. This is called the *molybdic* acid.

2. The metal molybdena may be extracted from its ore, which is a sulphuret of the metal. It is of a whitish yellow colour, and has been obtained only in the form of small brittle grains. It is infusible, and has as yet been applied to no use.

275. URANIUM. This metal was discovered, combined with a peculiar kind of impure sulphur. It has been obtained only in small quantities in the form of grains, of an iron grey colour, with considerable lustre.

Obs. It is very infusible, and of no use in the arts.

276. TUNGSTEN has been obtained in small quantities only; nature presents it combined with oxygen and lime, forming *calcareous oxide of tungsten.* From this ore the metal may be extracted by a certain process.

Obs. Tungsten combines with oxygen in a proportion to form an acid, called the *tungstic* acid. The metal is of the colour of iron, with considerable brilliancy. So far as is known, it is useless.

CLASS IV.

REFRACTORY METALS.

277. TITANIUM, is obtained in the metallic form with great difficulty, and of course its properties have been little examined. The colour of the metal is dark copper red, with a strong metallic lustre and infusible.

Obs. The metal is obtained from its red oxide, when this is exposed to an intense heat moistened with oil, and surrounded by charcoal in a crucible. The red oxide is found in Germany and France, and in many places in this country. Its uses are unknown.

278. Columbium. This metal was first extracted by Mr. Hatchett from a specimen of ore found at New-London, Connecticut.

279. The metal is found combined with oxygen and iron forming *ferruginous* oxide of columbium.

Obs. This metal has scarcely been obtained in a state of purity, it being extremely difficult to deprive it of its oxygen by any known means. It is of no use.

Remark. The metal called *Tantalum* is of the same with columbium.

280. Cerum was discovered by the Swedish chemists in an ore which was supposed to be tungsten. It never has been seen in the state of pure metal, so that little can be said of its properties. It is found in the state of an oxide, of a red or brownish red colour. No use has been made of this substance.

OF THE EARTHS.

281. Though there seems to be an almost infinite variety of earthy substances scattered over the surface of the globe, yet when they are examined by chemical analysis, we find with surprise, that all the earth and stones which we tread upon, as well as the rocks, and the numerous different specimens which adorn the cabinets of the curious, are composed of only a few elementary substances, the earths being only nine in number.

282. The alkaline earths are *barytes*, *strontites*, *lime*, and *magnesia*. The simple earths are *silex*, *alumine*, *zircon*, *glucine*, and *ittria*.

Obs. 1. The experiments of Sir Humphrey Davy have rendered it probable that the earths are metallic compounds. After his discovery that the alkalies, potash, soda, and ammonia, were constituted of metallic bases united to oxygen, the earths were submitted to the same analysis, by which these discoveries were made.

Barytes, strontites, lime and magnesia, each exhibited traces of a metallic nature by this treatment: so that at the present time, the writers on chemistry consider the earths as compounds of a metal with oxygen. The evidence that the simple earths are of a metallic nature, is however scarcely sufficient to induce belief of the fact. But their analogy in many respects to the alkaline earths is a sufficient reason why they should be arranged together.

2. All the earths when pure, are perfectly white.

283. *Barytes.* Pure barytes may be obtained from the sulphate of barytes, (a substance found in nature) by a chemical process.

Exp. Into an iron kettle put one part of finely powdered sulphate of barytes, and three parts of carbonate of potash, (common pearlash,) and a proper quantity of water. Let the water boil for an hour, breaking down the lumps into which the mixture is apt to run, with a pestle. A *carbonate* of barytes will be formed, because the earth gives its *sulphuric* acid to the potash, while the potash gives its *carbonic* acid to the earth. This is to be washed with boiling water, and then dissolved in dilute muriatic acid. This forms a *muriate* of barytes.

To the muriate of barytes add ammonia as long as any precipitate takes place; this throws down any metal that may be present. Then add carbonate of potash to the clear solution in a clean vessel, and pure carbonate of barytes will be precipitated. Expose the carbonate to an intense heat, in a crucible surrounded with charcoal, and the pure barytes will remain, the carbonic acid being driven off by the heat.

Remark. The carbonate of barytes formed in the first part of the process is only in a small proportion to the quantities of the materials.

284. Barytes in a pure form has a sharp caustic taste, and like other alkaline substances, changes vegetable blue colours to green. It is a strong poison.

285. Some preparations of barytes are used for chemical tests, others are used in medicine. The white pigment of miniature painters is pure barytes.

Obs. If a small quantity of water is added to recently prepared barytes, it is rapidly absorbed and solidified, producing a high degree of heat.

Illus. Pure barytes is a delicate test for the carbonate and sulphuric acids. The muriate is used as a remedy in some kinds of diseases, and also as a test.

286. The base of barytes is called *barium.*

Obs. The base of barytes was obtained by submitting the carbonate to the action of a powerful galvanic battery, in contact with quick-silver. By this means, an amalgam was formed, consisting of mercury and barium. This amalgam was introduced into a bent glass tube, the tube being afterwards filled with vapour of naptha. The naptha prevents the metal from absorbing oxygen. In this state, heat was applied to the amalgam until the mercury was driven off. The residium was a dark grey substance, resembling a metal; when this was exposed to the air, it rapidly absorbed oxygen and fell into a powder, which was barytes.

Remark. Sulphate of barytes is the heaviest of all earthy substances.

287. *Strontites*, or strontian, is named after the place where it was first discovered in Scotland. It very much resembles barytes in its external, as well as chemical qualities.

Illus. It occurs in nature in the state of a sulphate. The pure earth may be obtained from it by the same process as described for barytes, and on mixing a little muriate of strontian with alcohol, and burning it, the flame is tinged of a beautiful red, which is not the case when baryates is mixed with alcohol. These seem to be the principal means of distinguishing the two earths from each other.

The metallic base of strontites is called *strontium.* It is procured by exactly the same process as that described for barytium.

288. Lime exists in great abundance in the state of a carbonate. Limestone, marble, chalk, &c. are of this kind.

289. When the carbonate of lime is exposed to a red heat, the carbonic acid is driven off, and there remains a caustic white substance, called *quick-lime* or lime.

290. Lime absorbs water with remarkable avidity, at the same time much heat is extricated.

Obs. 1. The heat given out by the slacking of lime arises from the water, which passes from the liquid to the solid state.

Illus. Lime will absorb a considerable quantity of water and yet remain dry. Thus the water becomes solidified with the slacked lime, and forms a part of it.

Obs. 2. The degree of heat produced by the combination of lime and water is said to be 800 Fahrenheit. It is well known that vessels and buildings are sometimes set on fire in this way.

291. Lime is very sparingly soluble in water, viz. in the proportion of about 1 to 500 parts.

Obs. Lime water is so good a test of carbonic acid that it will become turbid by blowing the air from the lungs through it.

Remark. The air from the lungs always contains a quantity of carbonic acid.

Obs. When carbonic acid comes in contact with lime, it is absorbed with avidity. The carbonate is less soluble in water than lime itself; the turbidness, therefore, is occasioned by the insolubility of the newly formed carbonate of lime.

2. If lime water is evaporated in the ordinary way in the open air, the lime absorbs carbonic acid from the air, and falls to the bottom of the vessel in the form of a powder. If this precipitate is exposed to the action of an acid, the carbonic acid is again extricated, a proof that the air contains carbonic acid. That the air from the lungs contains this gas, may be shown in the same way.

292. Lime is quite essential to the comforts and conveniences of life; its employment being extended to many purposes for which there is no substitute.

Illus. The cement in which bricks are laid for the building of houses is composed of lime and fine sand. The plastering for the inside walls is composed of lime, sand, and hair. Lime is used in bleaching, for manure, in the process of tanning, &c.

293. The base of lime is called *calcium;* but it has never been obtained in sufficient quantity to examine its properties.

294. *Magnesia* in a few instances has been found in the native state, but always in small quantities. That sold by the apothecaries is obtained by the

decomposition of sulphate of magnesia, which is contained in solution in some mineral springs, as that of Epsom, and in sea water.

Illus. Magnesia is obtained from its combination with sulphuric acid as follows: Dissolve any quantity of Epsom salt in a large proportion of soft water, and gradually add to it a solution of pure carbonate of potash or soda. This will occasion a copious precipitate. The precipitate is collected by passing the solution through a cloth. This is boiled repeatedly with large quantities of pure water. It is then exposed to a red heat until a sample of it does not effervesce with acids. This is *calcined* magnesia.

Obs. In the above process, a double decomposition takes place: the sulphuric acid of the sulphate of magnesia, combines with the alkali, and forms sulphate of potash; while the carbonic acid of the alkali joins to the disengaged magnesia, and forms carbonate of magnesia. The heat drives off the carbonic acid, and calcined magnesia remains.

295. Magnesia is chiefly used in medicine.

Obs. It is given combined with sulphuric acid, forming *sulphate of magnesia,* called also Epsom salts, and in the form of *calcined* and *carbonate* of magnesia.

296. The metallic base of *magnesia* is called *magnesium.* The properties of this metal are unknown, it having never been obtained in a pure state.

297. *Silex,* or silicious earth, is the principal constituent of flints or flinty stones. Common gun flints are almost pure silex.

Illus. Silicious earth can be obtained from gun flints or common rock crystals, as follows. Expose the flints to a red heat, and while red hot, throw them into water. This makes them brittle. Then reduce them to a fine powder, and mix the powder with four times its weight of carbonate of potash, and expose the mixture to such a heat as to bring it into a state of complete fusion. We thus obtain a compound of alkali and silicious earth. Dissolve this in water and filter the solution; then add to the solution sulphuric acid. This will unite with the alkali, and the silex will be precipitated. The precipitate being washed, is silex nearly pure.

298. Silex is the base of almost all the stones which give fire with steel.

Illus. Jasper, quartz, chalcelony, agate, &c. are chiefly composed of silex. It is also deposited by vegetation in the bark of several kinds of plants. The sand of the sea and of rivers chiefly consist of it.

299. Pure silex is a white powder, perfectly tasteless and inodorous. It is not acted upon by any of the acids except the fluoric. (See fluoric acid.)

300. Silex in the form of white sand is used in the making of glass.

Illus. Glass is made by fusing together certain proportions of white sand, potash, and lead.

301. The base of silex is called *silicium*, but it has never been obtained in a separate state.

302. *Alumine* derives its name of alum, of which it is the base.

Obs. Aluminous earth may be obtained from the sulphate of alumine and potash, which is common alum, by an easy process. Make a solution of alum by dissolving in six parts of boiling water, one of alum. When the solution is cold, add a solution of carbonate of potash to that of the alum. This will throw down a carbonate of alumine, because the alkali unites to the sulphuric acid of the alum, while the carbonic acid of the alkali unites to the alumine. The precipitate being washed by agitating it in water, and then exposed to a red heat to drive off the carbonic acid, is *alumine.* It is, however, not perfectly pure, but will answer for common experiments.

303. When alumine is moistened with water it forms a cohesive mass, susceptible of being kneaded into regular forms.

Obs. 1. The tenacity of all sorts of clayey soils, or what is called argilaceous earth, &c. depends on the quantity of alumine which they contain. Some clays, as fullers' earth, are composed of little else than this substance. All soils contain more or less of it; and in what are called *clayey* soils it predominates. The colour of these soils is owing to the admixture of oxide of iron, vegetable matter, &c. with the alumine.

2. Several of the precious stones called gems, consist almost entirely of alumine: such are the *ruby* and the *sapphire*, which contain nothing except this earth and a little colouring matter.

3. *Alumine* is the chief ingredient in the clays used in pottery. It is also the basis of China ware, porcelain, &c.

304. The metallic base of alumine is called *alu-*

mium. Of the existence of such a metal there is only presumptive evidence, the metal having never been seen in a separate state: it is therefore chiefly from analogy that such a metal is supposed to exist.

305. *Zircon*. This earth was discovered by Klaproth in a precious stone from Ceylon, called *jargon* or *zircon*. It is also found in the hyacinth, another precious stone. Like all the other earths it has the form of a white powder. It has been found only in small quantities, and in no other substances except those above stated.

306. *Glucine* has also been discovered in small quantities only. It has heretofore been found only in a precious stone called *beryl*, the *emerald* of Peru, and in a stone called *gadonolite*.

Obs. It resembles alumine in several of its properties. In others it is different. With acids it has the peculiar property of forming a compound which is sweet to the taste. We have no knowledge of the base of this earth. If this is ever discovered to be a metal, its proper name will be *glucinum*.

307. *Ittria*. This earth has been detected in a stone called *gadonolite*, found in Sweden. It is white and smooth to the touch like alumine; but is not attacked by the pure alkalies, in which respect it differs from both alumine and glucine. Nothing is known of its base.

308. THORINA was discovered by Berzelius, a Swedish chemist in 1815. It was obtained from a species of the same stone which afforded the last mentioned earths, glucine and ittria. It differs from *glucine* and *alumine* by its insolubility in liquid potash; from ittria by its solutions being purely astringent without being sweet to the taste.

OF THE ALKALIES.

309. The alkalies have all of them an acrid, caustic taste; they are soluble with water; they form glass with silex by means of heat; they render oils miscible with water, or form soap; they change the red colours of vegetables to green; they unite to sulphur by fusion; they dissolve animal substances.

310. The alkalies at present known are four in number. Potash, soda, lithia, and ammonia. The three first are called fixed alkalies, because they do not evaporate in the open air, or at considerable degrees of heat. Ammonia is called the volatile alkali because it flies off in a gaseous form when exposed to the air.

Obs. ***Potash*** is so called from its being prepared or boiled down in *pots*. It is obtained by passing water through wood ashes and afterwards evaporating the water.

311. Potash may also be obtained from the lees of wine.

Obs. When the tartar of wine and nitre or salt petre are burned together, they afford the substance called *salt of tartar*. This is potash combined with carbonic acid in a tolerably pure state. It is the kind of carbonate of potash most commonly used in medicine. ***Salt of wormwood*** is the carbonate of potash, obtained by burning wormwood and treating the ashes as above described. It was formerly supposed to possess higher medicinal powers than the common carbonate of potash, but differs from it only in being more pure.

312. Potash is used in making soap, and glass, and in the process of bleaching.

Obs. ***Soft*** soap is made with potash, and ***hard*** soap with soda.

Obs. 2. Common green glass is made by fusing sand and wood ashes together by means of an intense heat made by dried wood. Flint glass is made by fusing a mixture of gound white quartz, or pure white sand, a proportion of lead and a small quantity of oxide of manganese together.

313. ***Common potash, salts of tartar, salt of worm-***

wood, and pearl-ash, are only different names for carbonate of potash.

Obs. Potash combines with two proportions of carbonic acid, forming two different salts. The first is called *sub-carbonate* and the other *carbonate* of potash. In the first the alkali is not fully saturated with the acid, but in the carbonate it is supposed to be saturated. Some authors use the term carbonate, for what is here called sub-carbonate, and *bi-carbonate* for carbonate.

314. Potash has been found to be a compound body, consisting of a metal called *potassium* and oxygen.

Obs. 1. This discovery was made by Sir Humphrey Davy. The decomposition is effected by a powerful galvanic battery. For this purpose a piece of pure potash, weighing 60 or 70 grains, is placed on a small insulated plate of platina, and the galvanic influence from a battery consisting of at least one hundred pairs of six inch plates, is passed through it. The decomposition of the potash instantly begins to take place ; small bubbles appear at the negative pole of the battery, having a high metallic lustre, like quicksilver. These globules are *potassium.*

Fig. 1

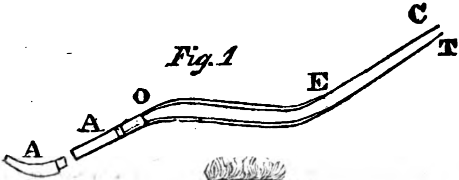
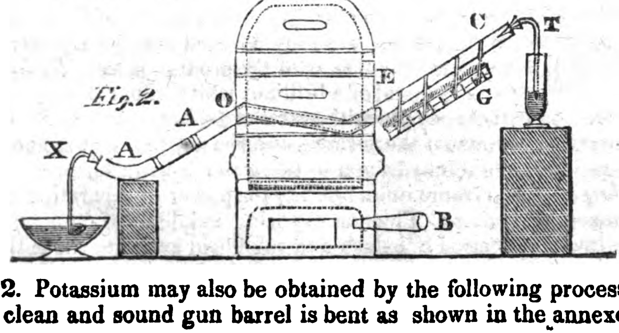


Fig. 2.



2. Potassium may also be obtained by the following process : A clean and sound gun barrel is bent as shown in the annexed

sketch, and covered with an infusible lute between the letters O and E (fig. 1) and the interior of the luted part is filled with clean iron turnings. Pieces of pure fused potash are then loosely placed in the barrel between E and C. A A is a copper tube, and small receiver, which are adapted to the extremity of the barrel O, and to each other by grinding. This apparatus is next transferred to the furnace, arranged as shown in fig. 2, X and T, representing two glass tubes dipped in cups of mercury. The furnace is supplied with air by a double bellows, entering at B, and a small wire basket G is suspended in the space between E and C. The part of the barrel in the furnace is now raised to a white heat, and the escape of air by the tube X shews that all is tight. Some burning charcoal is put at the end E of the cage G, which causes a portion of the potassa to liquify and fall into the low part of the gun barrel upon the iron. Hydrogen gas instantly escapes at the tube X, and attention must be had to keep the copper tubes A A cool by laying wet cloths on them. When the evolution of gas ceases, fresh charcoal is placed under the potassa, and so on till the whole has passed down; if too much potassa be suffered to fall at once, the extrication of gas at X will be very violent and should be avoided. If the space between A and O should become stopped by potassium, gas will issue by the tube T (which must always be under a greater pressure of quicksilver than at X) and it may be fused by applying hot charcoal to the tube, when the gas will again appear at X and cease at T. When the operation is concluded, the tubes X and T are removed, and corks quickly applied to the holes; and when the apparatus is cool, the barrel is carefully removed from the furnace and a little naptha suffered to run through it. The potassium is found in globules in the tube and receiver A A, and considerable portions often lodge at O. The success of this operation is certain, if the heat has been sufficient, but the barrel, if not carefully covered with lute, is apt to melt, and much, if not the whole, of the product is lost. *Brande.*

3. Potassium is a metal of a brilliant white colour, like quicksilver. It attracts oxygen with extreme avidity. When thrown on water, it swims on the surface, absorbs oxygen, and instantly takes fire, while the hydrogen of the water is evolved.

Expl. The galvanic influence has the power of separating the elements of bodies. Thus on exposing sulphate of potash, (a substance composed of potash and sulphuric acid,) to the action of a powerful galvanic battery, the salt is decomposed and pure potash is found at the negative pole, and sulphuric acid at the positive. The decomposition of the potash is on the same principle. Its elements are separated, the metal being attracted by the negative side of the battery, and the oxygen passing off at the positive.

315. It is stated above, that the substances commonly called potash, salts of tartar, &c. are *carbonate of potash.* When potash is divested of its carbonic acid, there remains an extremely active substance called *pure* or *caustic* potash.

Illus. To prepare pure potash, dissolve any quantity of pearlash in twice its weight of boiling water, and add to the solution, while hot, an equal weight of lime slacked in six times its weight of hot water. Boil the mixture half an hour, frequently stirring it. Then strain it through a cloth. The potash will be in solution. Boil this solution to dryness, and immediately cork it up. Where potash is wanted for nice experiments, it ought to be boiled down in a silver vessel, and re-dissolved in alcohol, after which the alcohol is distilled off in an alembic and the potash is fused.

Obs. This substance is called *hydrate of potash,* because it always contains a quantity of water, even after exposure to a high degree of heat.

It is used by surgeons as an escharotic.

316. *Soda* is obtained from the ashes of plants growing on the sea-coast, and particularly from the *salsola soda* which grows in great abundance in some parts of Spain. It also occurs in the mineral kingdom united with the *sulphuric*, *muriatic*, and *boracic acids.*

Illus. 1. The substance known in commerce under the name *barilla* is an impure carbonate of soda. It is made by burning the plant salsola soda. *Kelp* is a still more impure substance of the same kind, procured by burning various plants growing in the sea.

2. *Borax* is formed by the union of boracic acid and soda. It is found native in the East-Indies, Persia, &c.

317. *Sea salt* is a *muriate* of soda. The ocean is impregnated with it.

318. Soda is found in great abundance in Egypt in the form of a carbonate.

319. The article sold under the name of soda or

carbonate of soda, is obtained by the decomposition of sulphate of soda (Glaubers salts) or muriate of soda (sea salt.)

Illus. The decomposition of the sulphate of soda is effected by heating the salt with charcoal and chalk in a furnace. By this means the sulphuric acid is disengaged, while the soda absorbs carbonic acid from the charcoal and chalk. Thus a carbonate is formed instead of a sulphate.

The muriate of soda is decomposed by mixing with its solution in water, a solution of the carbonate of potash. Both these salts are decomposed. The muriatic acid of the muriate of soda, unites with the potash, forming a muriate of potash, while the carbonic acid of the potash unites to the soda, forming carbonate of soda.

320. The caustic or hydrate of soda may be obtained by following the process already described for potash.

321. In most of their properties potash and soda resemble each other. When pure they are both equally caustic, destroying the skin and flesh of animals, when suffered to touch them only for a few moments. They both form soap with oils, that made with soda being hard, and that with potash soft. They both form glass with silex by fusion, &c.

322. The base of soda, like that of potash is a metal. It is called *sodium*, and is obtained by exactly the same process as described for obtaining potassium. A stronger galvanic power is however required to decompose soda, than potash.

Obs. The base of soda agrees in most of its properties with that of potash. Both these metals are lighter than water. They are of a brilliant white colour, resembling quicksilver. Sodium is soft and malleable, and may be flattened into sheets by a slight pressure. Both of them absorb oxygen with surprising avidity. When thrown on water they decompose it with great violence. The action of potassium on water is attended with some beautiful phenomena. When thrown on it, or when brought in contact with a drop of water, an instantaneous explosion is produced, with a vehement flame. When sodium comes in contact with water, it produces a violent effervescence and a loud hissing noise, but does not produce an explosion attended with light and heat as potassium does.

323. The phenomona produced by both these substances when they come in contact with water, are consequences of the extreme rapidity with which they decompose it, by absorbing its oxygen and setting free its hydrogen.

Obs. It has been observed, that these two metals are obtained by depriving potash and soda completely of their oxygen.

When potassium or sodium is exposed to the air, it attracts oxygen and falls into powder, which on examination is found to be pure potash, or soda. When thrown into water, a solution of one of these substances is found to be the result.

These facts show beyond all doubt that the bases of potash and soda are of a metallic nature.

324. *Lithia*, or *lithina* is an alkali lately discovered in Sweden. It was first found in a mineral called *petalite*, and has since been detected in some other substances.

Obs. Lithia has been found in small quantities only. In its caustic qualities it resembles the other alkalies, as also in changing the blue colours of vegetables to green. In some of its properties, however, it is entirely distinct from potash, or soda, and particularly in possessing the power of neutralizing a much greater quantity of the different acids, than either of those alkalies. Like these, it unites to acids and forms a class of salts, none of which, however, have yet been applied to any use.

325. AMMONIA. Pure ammonia always exists in the state of a gas. It is obtained by the decomposition of *muriate of ammonia* commonly called *sal ammoniac.*

Exp. Mix together equal parts of muriate of ammonia and dry quicklime, each separately powdered, and introduce them into a flask, or small retort. Then apply the heat of a lamp and receive the gas over mercury.

Obs. A substitute for the mercurial bath, is described in the first part of this volume among the chemical utensils. This may be used in making experiments on ammonia, and such other gases as are absorbed by water, where a mercurial bath is not at hand.

326. This gas has a strong and pungent smell. It immediately extinguishes flame; but before a taper immersed in it goes out, the flame is enlarged by the addition of another of a pale yellow colour, which descends from the mouth to the bottom of the jar.

327. Ammonia is rapidly absorbed by water.

Illus. Water absorbs more than 500 times its bulk of this gas. The *volatile spirit of sal ammoniac* is prepared by impregnating water with this gas. When the cork is removed from a bottle of this liquid, some of the gas escapes, and gives the well known pungent smell of *spirit of hartshorn.* Alcohol also absorbs a portion of this gas, and constitutes what is called *ammoniated alcohol.*

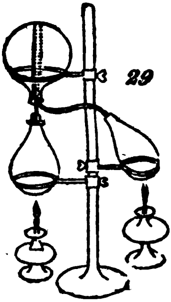
Obs. There is a great difference in the strength of the above preparation. A small degree of heat will expel every particle of the ammonia from either of them, and by exposure to the open air the gas gradually makes its escape. The consequence is, that this article is frequently sold when it contains but a very small quantity of ammonia.

328. The article of commerce called *sal ammoniac* was formerly brought from Egypt, where it was prepared from the soot of animal substances.

Illus. All animal matters contain ammonia. At the present time it is manufactured in Europe in great quantities. Several processes are used at the different manufactories. At Paris, sal ammoniac is made as follows. Two kilns are constructed of brick ; into one of these is put a mixture of sulphuric acid and common salt, and into the other animal matters, as horns, bones, parings of hides, &c. On the application of heat, there is extricated from the kiln containing the salt and acid, *muriatic acid gas*, and from the other ammonia. These gases are conducted by flues to a chamber lined with lead, where they combine together and form solid muriate of ammonia, which encrusts the roofs and sides of the room, and enters into solution with a stratum of water on the floor.

Expl. On the application of heat to a mixture of sulphuric acid and common salt, the muriatic acid of the salt comes off in the form of gas, it being set free in consequence of the combination of the sulphuric acid with the soda of the salt. The ammonia is extricated from the animal matter by the heat. When these two gases meet, they unite with each other, and are condensed in the form of muriate of ammonia.

Exp. The above mode of making sal ammoniac may be illustrated as follows:


29

Take two flasks furnished with tubes as in fig. 29. Into one of them put a handful of sea salt and pour on this an ounce or two of sulphuric acid. Into the other, put equal parts of powdered quicklime and sal ammoniac. Invert over the ends of both tubes a tall bell glass, or what is better a tubulated receiver, as seen in the figure. Then let a gentle heat be applied to the bottom of each flask. The two gases will be disengaged, and will form a white cloud, which will be condensed on the sides of the vessel. If one of the gases be introduced into the receiver without the other, it will remain transparent until it meets the other, when there is instantly formed the thick white cloud. This affords a very pretty experiment.

329. The article used in smelling bottles, and called *volatile salts*, *salts of hartshorn*, *&c.* is a carbonate of ammonia. It may be prepared by proceeding exactly as in the above experiment, except that carbonic acid must be substituted for the muriatic acid gas.—See 154.

330. Ammonia is a compound body. It is decomposed by electricity and separated into its elements, which are *hydrogen* and *nitrogen*.

331. It is suspected from some experiments made on ammonia, by means of galvanism, that its base is a metal. If this be the case, then the bases of hydrogen and nitrogen are also metals, as the base of ammonia consists of a union of the bases of hydrogen and nitrogen. This follows from the electrical analysis of ammonia, by which these two gasses alone are obtained.

Obs. This is a very curious subject, and one of great importance to the science of chemistry. If it should be proved that the bases of hydrogen and nitrogen are metals, a novelty no less than that of the existence of a metal, or a metallic oxide, in the state of a permanent gas, would be exhibited. At the same time it would of course be concluded, by analogy, that all the other aeriform bodies are also metals in some form or other. Nor is it likely that supposition would rest here, but in all probability, by a course of analogical reasoning, all substances, compound as well as simple, would be considered as possessing metallic bases, until the contrary should be proved. So that ultimately we should have no idea of a substance which was not metallic.

332. The evidence that ammonia is possessed of a metallic basis is as follows.

When mercury, negatively electrified, is placed in the galvanic circuit in contact with solution of ammonia, the mercury gradually expands to four or five times its former dimensions, and becomes a soft solid of the consistence of butter. By this process, the mercury acquires an addition to its weight of about one twelve thousandth part, and it is remarkable that its bulk is so increased by this small addition of weight, and its specific gravity is so lessened as to be only three times heavier than water, when before the process, it was about fourteen times heavier.

Obs. That the quicksilver in the above experiment absorbs a metal from the ammonia, and that the change which it undergoes, depends on this fact, is inferred thus. So far as known, the metals are the only bodies capable of amalgamating with mercury. When this takes place, the mercury still retains some of its characteristic properties, as for a time its lustre and colour, but loses others, as its fluidity. In the above instance the change produced by the ammonia, resembles the known effects of a metal on the mercury. In both cases it becomes a soft solid. Therefore the mercury has amalgamated with a metal, and if with a metal, it follows of course that this must be the base of ammonia.

All attempts to detach the metal of ammonia from the quicksilver and exhibit it in a separate form, have heretofore failed.

When however, the amalgam is exposed to the air, the mercury is revived, and a small quantity of ammonia is produced. Hence it is said that the metal *ammonium*, absorbs oxygen from the air, and falls into ammonia.

The intelligent reader will notice from the above account, that there is at present no very positive proof that the base of ammonia is of a metallic nature.

OF THE ACIDS.

333. The word *acid* is applied to all such substances as are possessed of one, or more, of the following properties.

They are sour to the taste.

Obs. This is very different, as to its degree in different acids. Some of them are so intensely sour as to burn the tongue, as the nitric and sulphuric acids. Others have this property only in a small degree.

334. They redden vegetable blue colours.

Obs. Hence blue vegetable infusions are good tests of the presence of uncombined acids. A piece of paper stained by rubbing it with the flower of larkspur, iris, &c. answers the same purpose. It turns red when touched with an acid.

335. They combine chemically with alkalies, earths, and metallic oxides, and form *salts*.

Obs. The peculiar qualities of both the acid and alkali are destroyed by this union.

Exp. Mix together the two caustic substances *pure soda* and *muriatic acid*, and there will be produced the mild compound, *common salt*.

Obs. Though the above are qualities which belong to most of the acids, yet some few of them are neither sour to the taste, nor do they redden vegetable colours. Thus the *prussic* acid has only the qualities enumerated under the third head. It forms salts with alkalies and oxides.

336. The acids are formed by the chemical union of oxygen with a base.

Obs. What are called *acidifiable bases*, are such substances as have the power of combining with such qualities of oxygen, as to form acids.

337. Some bases combine with oxygen in sever-

al proportions and form distinct acids, corresponding in some peculiar properties to each proportion of oxygen.

Illus. Sulphur unites with oxygen in two proportions, and forms two distinct acids. One of them exists in the form of a gas of a suffocating odour, which destroys vegetable colours; the other is a heavy liquid, which corrodes and destroys all kinds of vegetable and animal matters. These properties depend on the different proportions of oxygen which each contains.

338. The peculiar properties of the acids, and also their names are derived from their bases.

Illus. Sulphur, when combined with oxygen, forms sulphuric acid, carbon, carbonic acid, &c. The great difference between these two acids, depends on the sulphur and carbon, oxygen being the acidifying principle in both.

339. The proportion of oxygen with which a base has combined, is denoted by the name of the acid formed.

Illus. When a base has combined with its full proportion of oxygen, the name of the acid ends in *ic*. When the base has combined with only one proportion and is capable of receiving more, it ends in *ous*. Thus, sulphur, when united to one dose of oxygen, forms sulphur*ous* acid; when united to another dose it forms sulphur*ic* acid, and so of the other bases.

340. In some cases a combustible base, which affords an acid when fully oxygenated, constitutes only an oxide when combined with a less quantity of oxygen.

Illus. Carbon for instance, with one dose of oxygen, forms *carbonous oxide;* with another dose *carbonic* acid is formed.

341. Every acid, with a few exceptions, is capable of uniting with each individual of the alkalies, earths, and metallic oxides.

Obs. In every salt, therefore, there are present two distinct ingredients, viz. an acid, which is called the *salifying principle* and an alkali, an earth, or a metallic oxide.

342. The generic name of the salt is taken from the name of the acid.

Illus. In this respect, the several salts formed by the union of one acid with the different bases is a distinct class. Thus sulphuric acid forms with potash, *sulphate of potash*, with oxide of iron, *sulphate of iron, &c.*

343. The different acids, composed of the same base with different proportions of oxygen, form very different salts when combined with the same alkali.

Illus. The salt for instance which the sulphur*ous* acid forms with potash, is very unlike that which it forms with the sulphur*ic*,

344. The proportion of oxygen in the acid of which a salt is formed, is denoted by the termination of the generic name of the salt.

Illus. Thus salts, formed with an acid ending in *ous*, always ends in *ite;* as sulphur*ous* acid forms with potash, sulph*ite* of potash. Acids, ending in *ic*, form salts ending in *ate;* as sulphur*ic* acid forms sulph*ate* of potash.

345. In most cases the acid and base combine in such proportions, as that neither predominates, and consequently the compound formed is a *neutral* salt. In a few instances however, a neutral compound is capable of uniting with an additional quantity of acid, or of base, so that one predominates over the other.

Illus. Tartaric acid is capable of uniting with potash in a double proportion, so that the acid greatly predominates over the alkali. Such salts are distinguished by prefixing to their names the Latin preposition *super*. Thus we have *super* tartrate of potash, super sulphate of potash, &c.

346. When the base predominates, the deficiency of the acid is denoted by the preposition *sub*, as *sub* carbonate of potash, sub borate of soda, &c.

Obs. The pupil will see at once, with what ease the names and composition of a great variety of salts may be remembered, by observing the above rules. By knowing the name of a salt we know its composition. Thus muriate of soda is composed of soda and muriatic acid. If we know the composition of the salt, we also know its name. Thus a combination of muriatic acid and lime would make muriate of lime, and so of all other substances capable of forming salts.

347. The acids admit of being divided into three classes, according to the nature of their bases, or

the kingdoms of nature in which they exist, viz. *mineral*, *vegetable*, and *animal* acids.

MINERAL, AND METALLIC ACIDS.

Obs. These acids are composed of a simple base and oxygen.

	BASES.		BASES.
Sulphuric,	Sulphur.	Muriatic,	Unknown.
Sulphurous,			
Nitric,	Nitrogen.	Antimonic,	Antimony.
Nitrous,		Antimonious,	
Carbonic,	Carbon.	Chromic,	Chrome.
Boracic,	Boron.	Molybdic,	Molybdenum.
Phosphoric,	Phosphorus.	Molybdous,	
Phosphorus,		Tungstic,	Tungsten.
Arsenic,	Arsenic.	Columbic,	Columbium.
Arsenous,		Fluoric,	Unknown.

VEGETABLE ACIDS.

Obs. These acids all contain two simple substances as a base, viz. *carbon* and *hydrogen*. These are combined with *oxygen* forming acids.

Acetic,
Oxalic,
Tartaric,
Pyrotaric,
Gallic,
Citric,
Mallic,
Benzoic,
Pyroligneous,
Camphoric,
Subenic,
Kinic.

ANIMAL ACIDS.

Obs. Some of these acids, in addition to hydrogen and carbon as a base, contain nitrogen also. Oxygen, as usual, is considered the acidifying principle.

Phosphoric,
Lactic,
Saccholactic,
Formic
Sebacic,
Prussic,
Bombic,
Uric.

Obs. Some of the above acids are both animal and vegetable. Thus the prussic acid is found in plants as well as animals, Several of the mineral acids, as the sulphuric and muriatic, are found among animal bodies, &c.

MINERAL ACIDS.

348. *Sulphuric acid* is a heavy corrosive liquid, powerfully acid to the taste, but destitute of smell, and free from colour. It is formed by the combustion of sulphur.

Illus. Sulphur, in the open air, burns with a pale blue light and suffocating smell; but by burning it in oxygen gas, at the same time all moisture being excluded from under the vessel, a dense white vapour is produced, resembling snow. This is dry sulphuric acid.

Obs. When sulphur is burned in common air, sulphurous acid is formed. In this case the sulphur has not combined with its full dose of oxygen. When it is burned in oxygen gas it combines with its maximum of oxygen, and becomes sulphuric acid. When water, which has a strong attraction for this acid, is saturated with it, the common liquid sulphuric acid, or oil of vitriol is formed.

In the manufactories of this acid, the sulphur is mixed with a certain proportion of nitre, and the mixture is burned in chambers lined with lead. The nitre supplies the oxygen necessary to form sulphuric acid, which is absorbed as it is formed by water, with which the floor of the chamber is covered. This acid when concentrated by boiling, is about twice as heavy as water. A bottle of it is soon tinged brown by dropping into it, any vegetable matter. If stopped with a cork, this commonly has the same effect. This is caused by the carbonization of the vegetable matter, by the oxygen of the acid.

When this acid is mixed with water, in the proportion of about four of the former to one of the latter, the temperature of the mixture is raised to about 300 degrees.

349. When sulphuric acid is united to alkalies, earths, or metallic oxides, the compounds are termed sulphates.

Illus. The substance used as a manure, cement, &c. and called *plaister of paris*, is a compound of sulphuric acid and lime. It is therefore *sulphate of lime.* The article used in dyeing, and called copperas, is a compound of this acid and oxide of iron, or *sulphate of iron.*

Obs. Formerly sulphuric acid was obtained by the distillation of copperas, or, as it was also called, *green vitriol.* Hence this acid was called *oil of vitriol.*

350. This acid is decomposed by almost every individual of the class of combustibles, especially when assisted by heat.

Illus. When charcoal is immersed in hot sulphuric acid, the charcoal absorbs from it the oxygen which constitutes it sulphu*ric* acid, and it is in consequence converted into sulphur*ous* acid. Several of the metals produce the same effect by absorbing the oxygen.

Sulphuric acid is composed, in its dry state, of about 40 parts of sulphur, and 60 of oxygen to the 100. When liquid, and of the density of 1850, it contains 19 parts of water and 81 of the acid.

351. *Sulphurous acid* This acid exists in the form of a gas. It is produced when sulphur is burned in common air.

Exp. By means of a small spoon, or scoop, plunge some burning sulphur into a wide mouthed bottle filled with common air. As the sulphur burns, sulphurous acid gas is formed, which will soon fill the bottle. It must then be corked up.

352. This gas has a pungent and suffocating smell. It extinguishes burning bodies and destroys animals when they are made to breathe it. It has the property of whitening, or bleaching silk, straw, linen, cotton, &c. Water absorbs about 33 times its bulk of this gas. It is heavier than common air.

Exp. 1. Plunge a burning taper into a bottle of this gas, and it will be instantly extinguished.

Remark. It is so much heavier than atmospheric air that a bottle of it may be uncovered for a time without its escape; consequently these experiments are easily made, by covering the bottle with a plate of glass, and removing this whenever any thing is to be introduced.

Exp. 2. Its bleaching property may be shown by permitting any of the substances above mentioned to remain in it for a short time. Coloured flowers are turned white by it. They must be moistened with water before they are introduced.

353. Some of the metallic oxides are revived by the action of this gas.

Exp. Make a solution of acetate of lead in pure water, and with this moisten a piece of silk, or a small plant, as a sprig of mint, and while moist introduce it into a bottle of this gas. The metal will be revived and will cover the surface of the article with brilliant metallic lead.

Obs. Sulphurous acid has a strong tendency to combine with an additional quantity of oxygen. Acetate of lead is an oxide of the metal dissolved in an acid. When this is deprived of its oxygen, it returns again to the state of a metal. In the obove experiment the oxygen is absorbed by the acid, and consequently the oxide is revived.

354. *Nitric acid.* This acid is obtained from the salt called *nitre*, or *salt petre*. This is composed of nitric acid and potash. It is therefore nitrate of potash. The decomposition is effected by sulphuric acid.

Exp. Put into a glass retort four parts of nitre reduced to a coarse powder, and pour upon it three parts of strong sulphuric acid. Adapt a large tubulated receiver to the retort, and lute the junctures with a mixture of pipe clay, sand, and cut tow. Then apply the heat of a lamp or sand bath. The receiver must be kept cold during the process, and furnished with a tube of safety. The first product which passes over is red and smoking. This gradually diminishes, and the acid drops down pale, or colourless.

355. Nitric acid, made by the above experiment is not perfectly pure, but always contains a portion of muriatic and sulphuric acid.

Obs. Pure nitric acid always exists in the state of a gas. This, however, is found only in the laboratory of the chemist. What is commonly known by this name, contains a quantity of water, and forms what chemists distinguish by the name of *hydro nitric acid.* As this, however, is so generally known by the name of nitric acid, or aqua fortis, we shall continue to call it so at present.

356. Nitric acid when pure, is a colourless liquid considerably heavier than water. It emits white fumes when exposed to the air. It gives an indelible yellow stain to the skin. It becomes coloured by the sun's light, passing first to a straw colour, and then to a deep orange.

Obs. This change of colour is produced by the union of the light of the sun with the oxygen of the acid, in consequence of which, the acidifying principle suffers some diminution.

357. This acid retains its oxygen with but little force, and hence it is decomposed by all combustible bodies, which deprive it of its oxygen with more or less rapidity.

Exp. 1. Pour strong nitric acid on some warm, dry, and finely powdered charcoal. The charcoal will become ignited, giving out an immense quantity of fumes.

Obs. The charcoal absorbs the oxygen from the acid, with such rapidity as to produce ignition.

Exp. 2. Put half an ounce, or an ounce of oil of turpentine into a small cup; then pour on it suddenly about half an ounce of strong nitric acid. The turpentine will burst into flame with an explosion, sending forth an immense volume of black smoke.

Remark. In making this experiment, the vessel containing the acid must be tied to a stick, so that the operator may stand at a yard or two distant from the explosion.

Obs. The acid inflames the oil on the same principle that it ignites charcoal.

358. Nitric acid dissolves silver, copper, zinc, &c. The solution is more rapid if the acid is diluted with water.

Obs. This acid is called aqua fortis, and under this name is of important use in the arts.

359. When nitric acid is submitted to the action of copper, and some other metals, a part of its oxygen is imparted to the metal, and of consequence the nitr*ic* is converted into the nitr*ous acid.*

360. This acid combines with the alkalies, earths, and metallic oxides, and forms a class of compounds called *nitrates.* Most of these salts deflagrate when thrown on red hot charcoal.

361. *Nitrous acid.* When nitrate of potash is exposed to a degree of heat sufficient to deprive it of a part of its oxygen, and the process is then stopped, and the salt submitted to the action of sulphuric acid and heat, there comes over what is called *nitrous acid.*

Obs. When nitric acid is charged with the red fumes of nitrous gas, as in the beginning of the process for obtaining this acid, it is more commonly called nitrous acid. Indeed, chemists have doubted whether there exists an acid properly denominated nitrous, and which bore the same relation to the nitric, that sulphurous acid does to sulphuric. By the above process, an acid is obtained which contains less oxygen than the colourless nitric acid. But this same acid will become colourless by exposure to the air, the red fumes readily making their escape; and it is well known, that what is called nitric acid, contains various proportions of oxygen. Now whether what is denominated nitrous acid, is a definite, and distinct compound, or whether it is nitric acid containing a quantity of nitrous gas, which gives it colour, is a question on which chemists are divided. Mere dilution with water will change the colour of this acid. Thus the orange colour will pass through the shade of blue, olive, and bright green, by adding successive portions of water.

Some good authorities, however, maintain that the nitrous acid is a distinct compound, but it is difficult to point out to the student any distinctions by which the difference between the two acids may be obvious, except that the nitrous acid contains the red fumes of nitrous gas, while the nitric acid is without colour; still the coloured acid may be much stronger than the colourless.

It does not seem that the combinations of this acid with the different bases, afford compounds which differ from the nitrate, there being, it is believed, no compound which bears the name of *nitrite*

362. CARBONIC ACID. This acid when in a separate state, or uncombined with other substances, always exists in the state of a gas. It is perhaps more widely diffused than any other gas or acid. It is procured either by the direct combination of carbon with oxygen by combustion, or by expelling it from its natural union with lime by means of sulphuric acid.

Exp. Fill a bottle with oxygen gas and set it upright. Fasten a piece of charcoal of a cylindrical shape and two inches long, to a piece of wire, by winding the wire round one of its ends. Have the other end of the wire connected with the cork of the bottle. Ignite the lower end of the charcoal, and plunge it into the oxygen gas, putting the cork in its place. A vivid combustion of the charcoal will take place, attended with brilliant scintillations, affording a beautiful experiment.

Obs. On examination of the gas in the bottle, after the above experiment, it will be found that the oxygen has been converted into carbonic acid. This may be shown by passing a few bubbles of it into a vessel containing lime water. The water will instantly become turbid, and if suffered to stand, will deposite a white powder, which will again give out carbonic acid on treating it with sulphuric acid. It is therefore a carbonate of lime

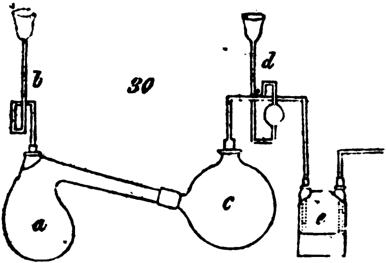
363. Although the combustion of charcoal in oxygen gas affords good proof of the constitution of carbonic acid, there is still further evidence that this gas is composed of carbon and oxygen. This consists in the analysis, or decomposition of the gas itself.

Exp. Provide a tube of very thin glass about one third of an inch wide and 18 or 20 inches long, sealed at one end. Coat it to within an inch of the sealed end with a lute of sand and clay; and when this is dry, put into it as much purified phosphorus in small pieces, as will fill the uncoated part. Then cover the phosphorus with pure white carbonate of lime. Let the part of the tube which contains the carbonate be made red hot by means of a chaffing dish of coals, or otherwise, and at this moment apply heat to the part containing the phosphorus, sufficient to convert it into a vapour. When the tube is cold, on breaking it apart, there will be found in it a small quantity of very light black powder, which is charcoal.

Obs. The heat expels carbonic acid from the carbonate of lime. Phosphorus, particularly when converted into vapour by heat, has a most powerful attraction for oxygen. In this experiment, the phosphorus attracts the oxygen from the carbonic acid, and the carbon is deposited, in the form of a black powder.

For a further account of carbonic acid, see the article carbon.

364. *Muriatic acid*, or spirit of sea salt, is obtained from common salt, by means of sulphuric acid assisted by heat.



Exp. Into a tubulated retort, (see fig. 30,) *a* put eight ounces of sea salt, and lute the retort to a large tubulated receiver. To the tubulure of the retort, fit the bent glass tube *b*, and to the aperture of the receiver *c*, adapt a tube twice bent at right angles, and furnished with a contrivance *d*, for preventing absorption. The longer leg of this tube terminates beneath the surface of water contained in the two necked bottle, *e*. From the other neck let another right angled tube proceed, which may terminate in another bottle containing water. The total quantity must be about five parts.

Let all the junctures be carefully luted with the fat lute, and when dry, pour very gradually through the bent tube, on the salt, five parts of strong sulphuric acid. Muriatic acid gas will be liberated in abundance and will pass through the receiver to the first bottle where it will be absorbed by the water. When this is saturated, it will be absorbed by the second bottle. When all the acid has been poured in, and the gas has ceased to issue, apply a gentle heat to the bottom of the retort. The water in the bottles, saturated with the muriatic acid gas constitutes *liquid muriatic acid*, sometimes called *marine* acid, *spirit of sea salt*, &c.

Obs. The pupil may not understand the uses of all parts of this apparatus. The bent tube *b*, prevents any of the gas from escaping in the room, since some of the sulphuric acid will remain in it, as is obvious on inspection. The use of the globe *c*, is to retain any vapor which comes over, that is condensible by cooling, as water mixed with sulphuric acid; the object of the experiment being to obtain the muriatic acid in a state of purity. The tube twice bent, *d*, and called a *Welters tube* of safety, after the inventor, is partly filled with water at the beginning of the experiment. This is to prevent absorption of the water from the two necked bottle into the receiver, in case a partial vacuum should be formed from the cooling of the retort. On inspection of the figure it will be obvious, that the pressure of the atmosphere would throw the water contained in the ball up the tube until the air rushed in. On the contrary, no gas can escape, because any pressure from within, would be followed by a high column of the water in the perpendicular part of the tube.

365. Liquid muriatic acid has the following properties.

It emits white suffocating fumes. These consist of muriatic acid gas, which become visible by contact with the moisture of the air. When heated in a retort, muriatic acid gas is disengaged and may be collected over mercury, or by the contrivance described in the beginning of this volume. Liquid muriatic acid is heavier than water. When perfectly pure it is colourless. It unites with alkalies, earths, and metallic oxides, and forms a class of salts called *muriates.*

Obs. The oxy-muriatic acid gas, otherwise called *chlorine,* has already been described.

366. *Boracic acid* is obtained from the *borate of soda,* commonly called *borax.*

Exp. To a solution of borax in boiling water, add half its weight of sulphuric acid, previously diluted with an equal quantity of water. Evaporate the solution a little, and on cooling, shining scaly crystals will appear. These are boracic acid. Let them be washed with pure water and dried on filtering paper.

Obs. In the above process, the borate of soda is decomposed by the sulphuric acid, which has a stronger attraction for the soda than the boracic acid has. The sulphuric acid and soda combine therefore, while the boracic acid is set free, and being nearly insoluble in cold water, is deposited in crystals at the bottom of the vessel.

367. This acid is destitute of smell and has very little taste because it is little soluble in the saliva. It melts into a glass which is permanent in the strongest fire. Boiling water takes up about one fiftieth part by weight of this salt. This solution reddens vegetable blues like the other acids, and effervesces with the alkaline carbonates.

368. It is soluble in alcohol, and the solution burns with a beautiful green flame.

369. The acid combines with the alkalies and earths and forms salts called *borates*. But the only important combinaton which it forms, is with soda. This compound is found native in India, and in the impure state in which it is imported, it is called *tincal,* or *brute* borax; when purified it forms the borax of apothecaries.

370. *Phosphoric acid,* is obtained by the oxigination of phosphorus by means of nitric acid.

Exp. About half fill a tubulated retort with nitric acid, and apply a gentle heat. When the acid is warm, drop into it through the aperture of the retort, a small piece of phosphorus, and instantly replace the stopper. The phosphorus will be dissolved with effervescence, and large quantities of nitrous gas will escape. When this has ceased drop in another piece, and repeat this until the last piece remains undissolved. Then raise the heat to drive off the nitric acid, and the phosphoric acid will remain in the retort, partly in the concrete and partly in the liquid form.

Obs. Phosphorus has a strong affinity for oxygen, which the nitric acid easily parts with. In the above experiment the phosphorus is oxiginated, and converted into an acid at the expense of the oxygen of the nitric acid. In conseqnence of this loss of oxygen, the *nitric* is converted into *nitrous acid* gas which escapes, and occasions the effervescence.

371. This acid has the following properties. It is soluble in water in all proportions. It produces a small degree of heat when mixed with water. It has a sour taste, but is not corrosive. With charcoal in a strong heat, it looses its oxygen and is again converted into phosphorus.

372. This acid combines with the different salifiable bases and forms a set of salts called *phosphates.*

373. This acid is found in the mineral, vegetable, and animal kingdoms. In the mineral king-

dom it is found combined with lead, iron, limestone, &c. forming phosphates of these substances. In Spain, whole mountains are composed of phosphate of lime. When any of this stone is thrown on burning coals, it burns with a beautiful green light, which lasts for some time.

374. In the vegetable kingdom, phosphorus or its acid is found in a great variety of plants. Various seeds and roots contain it, as potatoes, agaric, &c. It is also found in the charcoal of some kinds of wood, and the spontaneous combustion of this article by which powder mills have been blown up, has been in some instances attributed to this circumstance.

375. In the animal kingdom it is found in almost every animal substance, but particularly in the bones, which are composed almost entirely of the phosphate of lime.

376. *Phosphorus acid*, is obtained by exposing phosphorus to the atmosphere, from which it absorbs oxygen.

Exp. Let a stick of phosphorus be placed in a funnel, the pipe of which terminates in an empty bottle. It will slowly absorb oxygen from the air, and after some time will fall into the bottle in the liquid state of phosphorus acid.

377. This acid combines with the alkaline and earthy bases and forms *phosphites.*

Obs. When any of these salts are heated, they emit a phosphorescent flame. They detonate when heated with chlorate of potash. They are changed into phosphates by the absorption of oxygen, when mixed with nitric or oxy-muriatic acid.

Remark. The following are properly *metallic* acids, as they consist of metals united to such quantities of oxygen as to give them acid properties.

378. *Arsenous acid.* The article, commonly sold by the name of white arsenic is an oxide of the metal, but, as it fulfils one of the principle func-

tions of an acid, it has of late been called *arsenous* acid. This substance is in the form of a white powder of an acrid taste, and in solution with water reddens vegetable blues.

Obs. The arsenous acid sometimes occurs native, but is chiefly procured during the process of roasting the ores of other metals, which contain it. It comes sometimes in the form of lumps of an inch or more in diameter, and sometimes in the form of small crystals. Most of it is brought from Germany and is obtained from the ores of cobalt. These ores are roasted in furnaces terminated by long chimneys. The arsenic, of which they always contain more or less, is sublimed by the heat and concretes on the sides of the chimney, in the form of the white oxide, or arsenous acid, and from whence it is scraped off by condemned criminals. It is afterwards sublimed again to purify it, and then forms the article in question.

379. The arsenous acid combines with the alkalies and earths, and forms *arsenites*.

380. *Arsenic acid.* By repeated distillation with the nitric acid, the arsenous acid absorbs an additional quantity of oxygen from it, and becomes arsenic acid. This is a white concrete substance, possessing a sour and at the same time a metallic taste. It reddens vegetable blues, and effervesces strongly with alkaline solutions. It is a most active poison.

381. With alkalies, earths, and oxides, this acid constitutes the class of salts called *arsenates*.

382. *Antimonious acid* is formed by dissolving antimony in nitric acid, evaporating the solution to dryness, and igniting the product.

Obs. This is the substance commonly called white oxide of antimony, but as it combines with the salifiable bases and affords a class of salts, it is more properly ranked with the acids than with the oxides. These salts are called *antimonites*. Very little is known of them.

383. *Antimonic acid.* This is commonly known under the name of yellow oxide of antimony.

But as it combines with the earths and alkalies, it ought, like the antimonious, to be placed among the acids. These salts are called *antimoniates.* No common use is made of any of them.

384. *Chromic acid.* The metal called *chrome* is susceptible of three states of oxidizement. The first oxide is green, the second brown, and the third forms the chromic acid, which chrystallizes in the form of long prisms of a beautiful ruby red colour. This acid is obtained from its native combination with lead, with which it forms a chromate of that metal, and also from the chromate of iron a mineral found in abundance in the neigbourhood of Baltimore.

Obs. The chromic acid is obtained from the chromate of lead by treating this ore with carbonate of potash, and separating the alkali with a stronger acid.

385. None of the metallic acids part with their oxygen so readily as this.

Illus. If muriatic acid be distilled with chromic acid, the former absorbs oxygen from the latter and is converted into chlorine, while the latter, in consequence of the loss of oxygen is converted into an oxide of chrome.

386. The salts formed by the combination of this acid with the different bases, are called *chromates.*

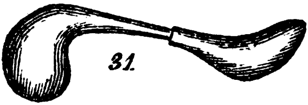
387. *Molybdic acid.* When the metal called Molybdenum is heated in the open air, it combines with a large quantity of oxygen, takes the volatile form and crystalizes in small needle-shaped white crystals. This compound of the metal and oxygen possesses acid properties. It is composed of molybdenum 74.5 and oxygen 25.5 to the 100.

388. *Molybdous acid* is formed, when two parts of the molybdic acid and one of the metal are sa-

turated together in boiling water, then filtered, and the solution evaporated in a slow heat. This acid is in the form of a fine blue powder.

Obs. Both of these acids combine with salifiable bases and form salts.

389. *Fluoric acid.* This acid is obtained from a mineral called *Derbyshire spar*, *fluor spar*, or more properly *fluate of lime*. In this substance the fluoric acid is combined with lime, and from whence it may be set free by the intervention of a stronger acid.



Exp. Into a retort of lead, see fig. 31, put some pure white fluor spar in fine powder, and mix it with twice its weight of sulphuric acid. Lute the retort to a receiver of the same metal with clay; then surround the receiver with a mixture of salt and snow or ice, and apply a moderate heat to the retort, taking care not to melt it. The fluoric acid will be extricated and pass into the receiver, where it is condensed by the cold into the liquid form.

Obs. The liquid obtained by the above process is called *hydro fluoric acid* because it is mixed with water. The water is expelled from the sulphuric acid by the heat.

390. This acid has the curious property of corroding glass, in consequence of its strong affinity for the silex which it contains. It therefore cannot be prepared or kept in glass vessels.

Illus. If a drop of it be placod on a piece of glass it quickly destroys its polish, and if permitted to remain on it, will eat into it to a considerable depth.

391. This acid acts with great energy on the animal fibre. If a drop of it strikes the hand, it raises a painful, and sometims occasions deep and dangerous ulcers. It is extremely volatile and emits dense white vapors, which the experimenter must be careful not to breathe.

392. The fluoric acid is used for the purpose of etching on glass.

Illus. The method of etching designs on glass is as follows. First cover a plate of glass of the size required with beeswax or engravers' varnish. The bees-wax must be spread over the surface as thin as possible. For this purpose heat the glass over a lamp, and at the same time rub the wax over its surface; then hold the glass in such a position that the wax will run off. If it is not too hot, enough will remain on to cover the surface.

Next draw the design by cutting the wax with a sharp instrument quite down to the glass, so that every line shall leave the surface naked. A large needle or sharp pointed pen-knife does well for this purpose. The etching is done by placing the plate in a horizontal position and pouring on the liquid fluoric acid. Where this cannot be obtained, the etching may be done with the acid in the state of gas. This requires only very simple apparatus. Take a common tin cup, large enough to include the piece of etching within the circle of its rim. On its bottom place a spoonful of powdered fluor spar, and then pour on strong sulphuric acid enough to make it into a paste. Next place the glass plate on the cup as a cover, with the etching downwards, and set the cup into a dish of hot water, or hold it over the flame of a lamp, taking care not to melt the wax. The fluoric acid in the state of gas will act upon the glass where it is not protected by the wax. In ten or fifteen minutes the etching will be done, when the wax must be rubbed off by heating the glass. In this way figures of any kind, as flowers, faces, names, &c. may be permanently and beautifully done on glass.

None of the salts called *fluates* are particularly interesting except the fluate of lime, from whence the acid is obtained.

VEGETABLE ACIDS.

Only the most important of these acids will be described.

393. *Acetic acid.* Distilled vinegar. The common vinegar is acetic acid mixed with a great proportion of water, and is called *acetous* acid. Vinegar differs from acetic acid only as it contains more water, a colouring matter, and other impurities, consequently it is the same acid in a state of dilution, so that properly there is no such acid as the *acetous.*

394. Vinegar is made by exposing to the action of the air, either cider, wine, beer, or any other liquid capable of undergoing the acetous fermentation. In all cases it must be exposed to the air, and warmed to a certain degree. In summer, the warmth is sufficient in a southern exposure.

Obs. In this process little or no gas is evolved, as in the vinous fermentation, but on the contrary, the oxygen of the atmosphere is absorbed; hence cider and wine run into vinegar, or become acidified by the actual absorption of oxygen, and on the same principle that acids are formed by combustion, only that light and heat in the latter case are not emitted.

395. Vinegar is also obtained by the distillation of wood.

Illus. The wood, first dried, is introduced into cast iron cylinders or retorts, which are exposed to a red heat. An immense quantity of inflammable gas is produced; and a liquid is condensed in the receiver, which consists of acetous acid holding in solution a quantity of tar and essential oil. These impurities by a certain process are entirely removed, so that the acid is colourless, and may be used for the common purposes of vinegar.

396. Vinegar may be purified by distillation, but it always contains a quantity of extractive matter, even after several distillations.

397. Pure acetic acid cannot be obtained by the distillation of the acetous acid, because the specific gravity of the real acid and water are so nearly alike that the water will rise along with the acid. But by presenting to the acetous acid some metal or alkali, for which it has an affinity, there will be formed a salt called an acetate, and from which the acetic acid may be expelled in its concentrated state.

Illus. Acetous acid combines with potash forming an acetate of potash. When this salt is distilled with half its weight of sulphuric acid, it is decomposed, a sulphate of potash is formed, and the vegetable acid is expelled in a very concentrated form, but mixed with a portion of the sulphuric acid. By digestion with manganese and a subsequent distillation, the acetic acid is obtained in a state of purity.

398. The acetate of copper, otherwise called crystallized verdigris also affords this acid by distillation.

Exp. Into a retort put some crystallized acetate of copper, and apply the heat of a sand bath. Acetic acid will come over tinged with green By a second distillation it is obtained pure. Its specific gravity is from 1056 to 1080.

Obs. The acetic acid may be still further purified, by mixing with it some caustic solid potash and then distilling again; when this is done a fluid is obtained which possesses some peculiar properties. It is colourless and as light as alcohol. It evaporates rapidly when exposed to the open air. It does not redden vegetable blues, and excepting that it mixes with water in any proportion, it has all the qualities of ether. Its smell is extremely pungent and it raises a blister when applied to the skin

399. *Oxalic acid*, or acid of sorrel. This is obtained by evaporating the fresh juice of sorrel to the consistence of honey, then putting it into a glass vessel and covering the surface with olive oil. After some weeks the sides of the vessel are covered with a crust which is the *salt of sorrel.*

Obs. The more common mode of preparing this acid is to acidify sugar with nitric acid.

Exp. To six ounces of nitric acid contained in a glass vessel, add by degrees one ounce of lump sugar. Nitrous gas will be disengaged in great abundance occasioning a violent effervescence. When all the sugar has been added evaporate a part of the acid and set the remaining liquor in a cool place to crystallize. Take these crystals and dissolve them in pure water, evaporate the water, and crystallize them a second time. Pure oxalic acid is then obtained in the form of small glistening needles.

400. This acid has a sour taste, and acts powerfully on vegetable colours.

401. It is used to take out ink spots. It is also one of the best tests of the presence of lime.

Exp. Dissolve some oxalic acid in *pure water* and let fall a few drops of it into well water. If the smallest quantity of lime be present there will be formed a white cloud, which being an insoluble oxalate of lime will afterward fall to the bottom of the vessel.

402. This acid forms with the different bases a set of salts called *oxalates*.

403. *Tartaric acid.* This acid is obtained from the supertartrate of potash (common cream of tartar.) Cream of tartar is the lees of wine purified.

404. The casks in which some kinds of wine are kept become encrusted with a hard substance, tinged with the colouring matter of the wine, and is otherwise impure. This substance is known in commerce by the name of *argol.* When this is purified by solution, filtration, and crystallization, it is called *cream, or crystals of tartar.* From this substance the tartaric acid is procured by the following process.

Exp. Let 100 parts of finely powdered cream of tartar, be intimately mixed with about 30 parts of pulverized chalk. This is best done by grinding them in a mortar and passing the mixture through a sieve. Let the mixture be thrown by spoonfulls into eight or ten parts of boiling water; waiting for the cessation of the violent effervessence, which is produced by each addition, before any more is thrown in. If it should appear that the acid is not fully neutralized by the above quantity of chalk, but that the solution reddens litmus paper, more chalk must be added until the paper is not changed by it.

By the above operation, the tartaric acid combines with the lime and an insoluble tartrate of lime is found at the bottom of the vessel. Decant the liquor into another vessel, and having collected the tartrate of lime, wash it three or four times with cold water. Then to the tartrate of lime thrown into a convenient quantity of water, add strong sulphuric acid, equal in weight to that of the chalk employed. The sulphuric acid combines with the lime and forms a sulphate, which is insoluble in the water, it therefore falls to the bottom of the vessel in the form of a white powder.

Let the acid and precipitate remain together twenty-four hours, frequently stirring them, then let the precipitate subside and decant the clear liquor, which will contain the tartaric acid in solution, together with some sulphuric acid and a small quantity of sulphate of lime. This is to be evaporated by a gentle heat, now and then decanting it from one vessel to another to get rid of the sulphate of lime which falls down. Finally, after the solution is evaporated to rather more than a fourth of the original quantity, set it away to crystallize. The crystals will be brown and must be purified by again dissolving them in water, evaporating and crystallizing, and this must be repeated until the crystals are pure, white *tartaric acid.*

405. In the manufactories of this article, some additional processes are used by which a larger quantity of the acid is obtained from the same quantity of materials, than can be obtained by the above process.

406. This acid and the carbonate of soda form the *soda powders*, of which great quantities are prepared and sold during the hot season.

Obs. The acid is pulverized and put into a paper by itself. Another paper contains the soda also in fine powder and dried, so as to deprive it of the water of crystalization. By trial it is ascertained, what quantity of the soda is required to saturate a given number of grains of the acid, and the powders are proportioned accordingly. To prepare soda water from these powders, the acid is dissolved in a tumbler of cold water, mixed with a little syrup or not, as suits the taste: the soda is then thrown in and the water is drank during the effervescence.

The effervescence is occasioned by the escape of the carbonic acid of the carbonate of soda; this being set at liberty in consequence of the union between the soda and the tartaric acid.

407. *Gallic acid.* This acid is found in abundance in nut-galls, and in less quantities in many other substances. It may be procured by several different processes.

Exp. 1. Put some pounded nut-galls into a retort and apply the heat of a sand bath or lamp. The gallic acid will rise and be condensed in the neck of the retort in a solid form.

2. Boil an ounce of powdered galls in sixteen ounces of water, down to eight, and strain the decoction. Precipitate also two ounces of alum dissolved in water with a sufficient quantity of carbonate of potash, and after having washed the precipitate

well, add it to the decoction of galls and digest the mixture 24 hours, shaking it frequently. The alumine of the alum combines with, and carries down both the tan and extract; and the filtered solution yields, by gentle evaporation, crystals of gallic acid.

408. This acid precipitates most of the metals from their solutions. The precipitates from solutions of gold, silver, and copper, are brown; from lead, white; from mercury, orange; bismuth, yellow; and from iron, deep black.

409. Gallic acid is of great importance, as it forms the base of ink, and is one of the principal ingredients in those dyes which colour black, or any of its shades.

Obs. It instantly strikes a black with solutions of iron. Hence a decoction of nut galls is used as a test for iron.

410. Ink is made by adding sulphate of iron to a decoction of galls. Hence ink is in part composed of gallate of iron. In addition to these ingredients it contains gum, which is added to hold the gallate in suspension and prevent it settling to the bottom, which would be the case were the solution made of pure water.

Obs. The following is said to be the best method of making ink.

Take eight ounces of Aleppo galls (in coarse powder;) four ounces of logwood (in thin chips;) four ounces of sulphate of iron; one ounce of sulphate of copper (blue vitriol;) three ounces of gum-arabic (in powder;) and one ounce of sugar candy. Boil the galls and logwood together in twelve pounds of water for one hour, or until half the liquid has evaporated. Strain the decoction through a cloth and then add the other ingredients. Stir the mixture till the whole is dissolved, and leave it 24 hours to subside. Then decant the ink and preserve it in glass or stone ware bottles well corked.

411. *Citric acid*, otherwise called *salt of lemons*, is found in the juice of limes and lemons, along with a quantity of extractive matter and mucilage, and with variable proportions of malic, and some-

times acetic acid. It is sometimes obtained in a separate and pure state, by first saturating the expressed juice with chalk, by which a citrate of lime is formed, and afterwards by decomposing this salt by means of sulphuric acid.

Illus. To the expressed juice of lemons or limes, add very gradually, finely powdered carbonate of lime, or what is sold under the name of *whiting*, and stir the mixture after each addition. An effervescence will ensue: and as long as this arises, fresh portions of the chalk must be added. When the effervescence ceases and the liquor has lost its sour taste, allow the mixture to settle; decant it into another vessel, and add a quantity of water. Let the powder again subside, and decant again, and do this as long as the water comes off turbid. The insoluble precipitate is the lime united to the citric acid.

The object now is to separate the lime, and obtain the acid in its pure state. For this purpose, pour upon the citrate of lime a quantity of sulphuric acid, equal in weight to the chalk employed, having first diluted with ten parts of water, and proceed exactly as has already been described for obtaining tartaric acid.

412. Pure citric acid forms beautiful transparent crystals, which are very soluble in water; an ounce of the fluid dissolves more than an equal weight of the salt.

413. This acid dissolved in water, is used as a cooling beverage in fevers. When drank in large quantity, it is said to be an antidote against the effects of opium, when taken in an over dose. With the bases it forms salts called *citrates*.

414. *Malic acid.* This gives the sour taste to fruits, as apples, gooseberries, &c. From these and other sour fruits it may be obtained, by a process similar to those described for obtaining the tartaric and citric acids.

This acid combines with some of the bases and forms *malates*. No use has been made of these salts.

415. *Pyroligneous acid*, or acid of burnt wood, is obtained by the destructive distillation of wood in iron retorts.

Illus. When this acid is manufactured in large quantities, a furnace is constructed of brick, through which pass cast iron cylinders, of a capacity to hold several hundred pounds of wood. The ends of the cylinders project a few inches through the brick on each side of the furnace. Both ends of the cylinders are furnished with cast iron discs or covers, nicely fitted. From one of the discs there proceeds an iron tube, which passes through a vessel of cold water to condense the acid. The other end is called the mouth of the retort. Here the wood is put in. The hard woods, as oak, birch, beech, &c. alone are used. Pine does not answer. When the retort is filled, the disc is put in its place, and made airtight by luting. A fire is then kindled in the furnace and kept up during the day. At night it is suffered to go out, and in the morning the charcoal is removed, and a new charge of wood introduced. The acid is received into proper vessels for use. It is of a deep brown colour, and much contaminated with tar, charcoal, &c.

416. Pyroligneous acid has lately been discovered to possess the property of preventing the decomposition of animal substances. "It is sufficient," it is said, "to plunge meat for a few moments into this acid, to preserve it as long as you please."

Obs. 1. The following facts on this subject, are contained in the 5th number of the Edinburgh Philosophical Journal,

If fish be simply dipped in re-distilled pyroligneous acid, of the specific gravity of 1.012. and dried in the shade, they preserve perfectly well. A number of haddocks were cleansed, split and slightly sprinkled with salt for six hours. After being drained they were dipped in the acid for about three seconds, and hung up in the shade for about six days. On being broiled, the fish were of an uncommonly fine flavour and perfectly white.

Obs. 2. The following facts on the same subject, are from the London Medical Intelligencer. The writer is Dr. Stanley. Having, he says, made several experiments on the above named acid, the results of which were favourable, on the 6th of October, 1819, I prepared two pieces of fresh meat (beef) with the purified acid, applying it lightly over their surfaces, by means of a small brush.

After hanging up in my kitchen till the 12th of November following, I gave one of the specimens to the captain of a vessel bound for the West Indies, with directions to observe and note any shange that might take place during the voyage, and to bring it back to me on the return of the ship to port. In the month of October, 1820, he restored to me the specimen. He had examined it several times on the voyage out and during his stay of some months at the island of Tobago, as did several gentlem resident there, but no perceptible change could be detected. On comparing it with the specimen kept at home I could observe no sensible difference in their appearance.

On the 21st of December following, I caused both to be thoroughly broiled, and when served up, they were declared by several gentlemen who tasted them with me, to be perfectly fresh and sweet, and with the addition of salt and vegetables, a palatable and wholesome dish.

417. It is well known that flesh and fish can be preserved by smoking when very little salt is used. Hams, tongues, herrings, &c. are kept in this way. The above facts account for this circumstance. The smoke is in part composed of pyroligneous acid. It is this then which preserves smoked meats from putrefaction.

418. The presence of an acid in smoke also accounts for its being so offensive to the eyes.

419. It was long thought that the pyroligneous was a peculiar acid, but latter experiments have shown that it is nothing more than the acetic acid, containing impurities. If this acid be several times rectified by distillation, there rises at last, strong and colourless acetic acid fit for culinary purposes. In some parts of Scotland, *wood vinegar* is manufactured in large quantities, by the same process which has been described for obtaining pyroligneous acid, only that in addition to that process, the acid is purified by re-distillation. Thus the impure acid of wood is called pyroligenous, but when purified it becomes *wood vinegar* or acetic acid.

Obs. After the acid is purified by being once distilled, it is in a proper state for preserving meat; but when it is perfectly pure, and in the form of acetic acid, it still has more or less the same property.

Phosphoric acid. See phosphorus.

420. Lactic acid. This acid forms a component part of sour milk. No use is made of it in the arts or otherwise.

421. Formic acid, or the acid of *ants*, is procured by the distillation of that insect.

Illus. A quantity of red ants are put into three times their weight of water and distilled. The product is saturated with carbonate of potash, which forms a *formate* of potash. The formic acid is procured by decomposing this salt by means of sulphuric acid. This acid possesses some peculiar properties which distinguishes it from all others. It is of no use.

422. *Prussic acid*, called also *hydrocyanic acid*, is considered as an animal product, though it is also contained in some species of plants. It is chiefly obtained from Prussian blue; but a plant called *lauro cerasus*, and several kinds of nuts, or kernels also yield it by distillation; among these are the kernels of bitter almonds, and those of the peach, wild cherry, and several others.

Obs. Prussian blue is made by calcining blood or other animal matter, with carbonate of potash, to which are afterwards added solutions of alum and copperas. This addition occasions a precipitate, which is at first green, but becomes of a beautiful blue, on the addition of muriatic acid. This precipitate being washed and dried, is the common prussian blue. Its composition is prussiate of iron mixed with the earth alumine.

423. Prussiate of iron is decomposed by red oxide of mercury and prussiate of mercury is formed. This latter salt is decomposed by iron and sulphuric acid, and the prussic acid is set free. These are the principles on which the prussic acid is obtained.

Illus. Mix together in a convenient vessel, 4 ounces of finely powdered prussian blue, 2 1-2 ounces of red oxide of mercury (red precipitate,) and 12 ounces of water. Boil the mixture for half an hour. The blue colour will disappear, and the solution will become yellowish green. Filter the solution and wash the residuum by pouring on boiling water enough to make up the loss by evaporation; let this also pass through the filter. Put the solution which is a prussiate of mercury into a retort, containing two ounces of clean iron filings. Connect the retort with a receiver, and place them on the lamp furnace, as in fig. 32, taking care that the juncture is made air tight, which may be done by winding a wet rag round the neck of the retort. Next pour into the retort one ounce of sulphuric acid diluted with three or four parts of water, and stop its tubulure by passing in a strait glass tube, which has already been prepared by being passed through a cork, or wound with a piece of wet rag. The lamp is now to be lighted, and the distillation carried on with a slow heat until three ounces of prussic acid are obtained.

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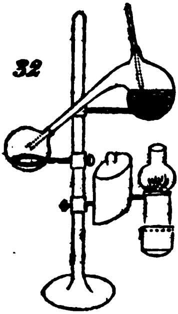


Caution. As the fumes are poisonous when breathed, it is proper to set the apparatus in a fire place, so that if any escape they may go up the chimney.

The receiver must be kept cold, and protected from the light by surrounding it with a wet cloth.

As this acid is decomposed by light and warmth, it must be kept in a cool and dark place. Even these precautions do not prevent its decomposition for more than two or three months.

Obs. The young pupil may not understand every part of the above process without some explanation.

In the prussian blue, the prussic acid exists in combination with iron. The red oxide of mercury having a stronger affinity for the acid than the iron has, the prussian blue is decomposed, and a *prussiate of mercury* is formed which is soluble in water. On the addition of the iron filings and sulphuric acid to this solution, the iron absorbs the oxygen from the mercury, which is then precipitated in its metallic state; and at the same instant that the iron is oxidized, it is dissolved by the sulphuric acid. Thus then the prussic acid is set free, because it does not unite with metals, but only with their oxides, and as the iron deprives the prussiate of mercury of its oxygen, the prussic acid remains detached in the solution of *sulphate of iron*. Now the prussic acid being volatile, while the sulphate of iron is not, it is easy to obtain it by distillation.

424. Prussic acid is a colourless fluid, like water. It has a strong smell resembling peach blossoms, or bitter almonds; this is so strong as sometimes to excite coughing. Some persons feel a slight stricture across the chest, or pain in the head on breathing it. Animals placed in its vapour, die in a few minutes. When given in large quantities it produces death in two or three minutes. It is indeed the most prompt and active of all poisons. It soon loses these properties on being exposed to the open air, the light also decomposes it in a short time.

Caution. The pupil, on account of the complicated process, and the poisonous qualities of this acid, had better not attempt to make it, until he has considerable knowledge of practical chemistry.

Obs. This acid is used in doses of a few drops as a medicine, in diseases of the lungs, indigestion, &c.

425. *Sebacic acid*, may be obtained from various species of animal fat.

Illus. To hog's lard, melted in an iron kettle add pulverized quicklime, and stir the mixture for a few minutes, raising the heat towards the end of the process. When the lard is cold, pour on it a large quantity of water; boil them together and filter the liquor. A brown acid salt will separate on cooling, consisting of lime united with the sebacic acid. The acid is obtained in a separate state by mixing this salt with a sulphuric acid in a retort and distilling. The acid in question rises in the form of a white liquid, which has a penetrating smell, and reddens vegetable blues.

OF THE SALTS.

426. The compound resulting from the union of an acid wih an alkali, an earth. or a metallic oxide, is called a *salt*.

427. The substance which combines with the acid to form a salt, is called the *base*. Thus *soda* is the *base* of muriate of soda.

428. When the base has combined with such a quantity of an acid as completely to destroy the peculiar properties of both the acid and the base, the acid is said to be *saturated*, and both acid and base are said to be *neutralized*. Such compounds are called *neutral* salts. Glauber's and Epsom salts are of this kind.

429. When a salt contains more acid than the base saturates, or when the acid predominates the latin preposition *super*, is prefixed to its name, as *supertartrate* of *potash*. Such salts are often sour to the taste.

430. When the salt contains more of the base than is saturated by the acid, or when the base predominates, this circumstance is denoted by the preposition *sub*, as *subcarbonate* of *potash*.

431. Most of the salts are soluble in water, though some are insoluble. While they are dissolving they absorb heat, and consequently produce cold. This phenomenon is explained by Dr. Black's law,—see Caloric.

432. When water is saturated with one salt, it is not thereby prevented from taking up another. Thus a given quantity of water will dissolve a certain portion of carbonate of lime and no more, but is still capable of dissolving as much potash as though it held no lime in solution, and after being saturated with potash will dissolve sugar, &c.

Remark 1. The explanation of the nomenclature belonging to the salts has been given in the remarks on acids in general.

2. Only the most important among the salts will be described.

SULPHATES.

433. The sulphates, when heated to redness with charcoal, form sulphurets. When tested with

solution of barytes, they furnish copious precipitations.

434. *Sulphate of soda*, or Glauber's salt. This salt is chiefly prepared from that which remains in the retort after the distillation of muriatic acid. It will be remembered that muriatic acid is obtained by distilling a mixture of common salt and sulphuric acid. The latter acid combining with the soda of the salt, forms sulphate of soda, while the muriatic acid is set free. This new salt being dissolved in water and saturated with carbonate of soda, in case the acid predominates, forms the common Glauber's salt.

Obs. 1. This salt forms regular transparent crystals of a prismatic figure, terminated by pyramids truncated near their base.

2. Its water of crystalization amounts to about half the weight of the salt.

3. Is is strictly a *neutral* salt, as neither the alkali, nor acid predominates.

4. It is very soluble in water, three parts of which at 60 degrees dissolves one of the salt. It is composed of soda 46, and acid 54, to the 100.

Its use as a medicine, is well known.

435. *Sulphate of Barytes*. This salt is found native, and is sometimes called *baro-selinite*, or *heavy spar*. It can also be formed by mixing the earth, barytes with sulphuric acid. In the native state it is a white, or yellowish stone of a crystalline appearance, being composed of lamallar crystals, which when broken present plane shining faces. One of its most remarkable properties is its great weight, being heavier, bulk for bulk, than any other earthy substance.

436. Sulphate of barytes, when treated in a certain manner affords one of the solar phosphori.

Illus. The native sulphate being powdered and ignited, is sifted and mixed with mucilage of gum arabic. This is then divided into cylinders of one fourth of an inch in thickness.

These after being dried in a moderate heat, are to be exposed to the heat of a wind furnace, placed in the midst of the charcoal. When the fuel is half consumed it must be replenished, and suffered to burn out. The cylinders will be found retaining their original shapes among the ashes. They must be preserved in a well stopped vial.

This phosphorus, after being exposed a few minutes to the sun's rays, shines in the dark sufficiently to render visible the dial of a watch.

437. Sulphate of barytes, artificially formed, is composed of about 66 barytes and 34 acid to the 100.

438. *Sulphate of Lime*, is found native in great abundance, and is known under the name of *plaster* of *Paris*, *gypsum*, &c. It is chiefly employed as a manure. It is also used as a cement.

Obs. It contains about 21 per cent of water, which is easily evaporated when the salt is exposed to a low red heat. What remains is an impalpable powder of a beautiful white. This powder is composed of lime 58, and acid 42 = 100.

439. *Sulphate of Magnesia*, or Epsom salt. This salt is obtained by the evaporation of the water of some springs which contain it in solution. It is also found in sea water, and is sometimes prepared from what is called the *bittern*, which remains after the common salt is extracted. It is easily composed by mixing together its ingredients, sulphuric acid diluted with water and magnesia.

Obs. Sulphate of magnesia crystallizes in the form of small quadrangular shining prisms. It undergoes no change when exposed to the air; is very soluble in water and undergoes a watery fusion when exposed to heat. Its principal use is as a medicine. It is composed of water 50, acid 33.5 and magnesia 16.5 to the 100.

440. *Sulphate of Alumine*. Common alum. The alum of commerce is dug out of the earth, where it is found in the native state, sometimes tolerably pure and in large masses, and sometimes diffused in beds of clay, or slate, or intermixed with various other substances.

Obs. 1. When it is found ready formed in earths, or friable minerals, it is extracted by collecting the earth into proper vessels, and pouring on water, which passes through, dissolves the alum and holds it in solution. The water is then evaporated until the salt crystallizes.

2. When the mineral which furnishes this salt is an aluminous clay mixed with sulphur and iron, another method is taken. Here, although most of the ingredients which form alum are present, yet no salt is formed. To form the salt the clay containing the iron and sulphur is exposed to heat, or merely to the air until the sulphur becomes acidified or converted into sulphuric acid, this then unites to the alumine and forms a sulphate. If no potash be present in the earth, a quantity is added, as this is necessary to form alum. The clay is then treated by lixiviation and evaporation as above.

3. The uses and common properties of alum are so well known as to need no description.

441. A combination of alumine, sulphur, and charcoal forms *Homberg's pyrophorus.*

Illus. To prepare this, powder an ounce or two of alum and mix with it an equal quantity of brown sugar. Put the mixture into a ladle, or earthern dish, and keep it stirring over a fire until all the water is driven off. Then pulverize it finely, and introduce it into a common vial coated with a mixture of clay and sand. Lute to the mouth of the vial a small glass tube, or stem of a tobacco pipe, to allow the moisture and gases to escape. The vial must then be set in a crucible surrounded by sand, and the whole set in a fire and gradually heated to redness. Water will soon issue from the end of the tube, and afterwards a gas, which on being lighted, burns with a blue flame.

After the flame goes out, keep up the heat for about fifteen minutes, and then remove the crucible from the fire, and immediately stop the orifice of the tube with a piece of clay. When the vial is cool enough to be handled, the pyrophorus must be hastily poured into warm and perfectly dry vials and corked from the air. It will be in the form of a black powder.

442. This powder is a curiosity, and sometimes a convenience.

Illus. If it is exposed to the air, it undergoes spontaneous ignition, giving out the smell of sulphur, and glowing with a red heat. If a small quantity be poured on a piece of paper it sets it on fire. If the vial is held a few feet from the ground and it is shaken out, a little at a time, it resembles a shower of fire.

In oxygen gas it burns or explodes with violence, giving out intense heat and light, affording a beautiful experiment.

443. Small vials filled with it may be kept for years, provided care be taken to prevent access of air. The most effectual method is to immerse their mouths under mercury.

Obs. 1. This powder affords a convenient method of obtaining fire for common purposes.

2. In regard to the chemical changes which the alum and sugar undergo to form this curious substance, Mr. Accum supposes that the red heat to which they are exposed, causes the sulphuric acid which the alum contains, and the charcoal to which the sugar is reduced, to react on each other, by which, part of the charcoal is converted into carbonic acid and is driven off in that form, at the same time the oxygen which the sulphuric acid imparts to the carbon, converts a part of this into sulphurous acid, which also makes it escape; the blue flame is probably caused by sulphurated hydrogen; the hydrogen being formed by the absorption of the oxygen of the water, by the carbon of the sugar. The remainder of the sulphur unites to the potash of the alum and forms sulphuret of potash.

Thus the powder consists of sulpuret of potash, alumine and carbon. When this is exposed to the air the sulphuret absorbs the oxygen, not only from the air itself, but also from the water which it contains with such avidity, as to occasion a degree of heat which sets fire to the charcoal and sulphur.

NITRATES.

444. The nitrates by the action of fire, furnish oxgen gas. Most of them scintillate when thrown on burning charcoal.

Obs. This last effect is in consequence of their increasing the combustion by imparting oxygen gas. Hence most of the nitrates are capable of supporting combustion.

445. *Nitrate of Potash.* Nitre. Saltpetre. This well known substance is found native in all countries, where circumstances are favourable to its production. It however seldom occurs in large masses, but is generally found either in the form of a whitish efflorescence on the soil, or in small

masses, or incrustations in limestone caverns. Its particles are also diffused through particular kinds of soil, but never to any considerable depth.

Obs. 1. The mode of obtaining nitre is by *lixiviation*, that is by passing water through the earth which contains it. The water dissolves the nitre, which is then crystalized by evaporation.

2. The calcareous caverns which abound in Kentucky furnish large quantities of this salt. One of these, situated in Madison county, is upwards of 600 yards in length and about 40 feet wide. It extends through a hill, and affords a passage for horses and waggons to bring out the earth to be lixiviated. One bushel of this earth yields from one, to two pounds of nitre.

3. The earth taken from under old and decayed buildings, which have been inhabited, always contains a quantity of this salt, and is sometimes lixiviated for this purpose. During our revolutionary struggle, considerable quantities of nitre were manufactured in this way.

446. The formation of nitre depends on circumstances which are easily imitated by art. Hence a considerable proportion of what is used in the arts, is produced by what are called *artificial nitre beds.* These consist of certain materials thrown together in heaps, with attention to the circumstances which are known to favour its production.

Illus. These beds are made by digging dry ditches, which are covered from the rain by sheds open at both ends, for admitting the air, which appears to be an important part of the process.

These ditches are filled with the earth from old and decayed buildings, as old mortar, dirt from cellars, &c. The refuse of slaughter houses, as bits of skin, horns, &c. are added, as also the soil from barn yards, &c. These substances being mixed together in the heap, are now and then turned up with a spade to expose all parts to the air. After a succession of several months, or less, according to the management of the operation, the nitre forms in the mass and is obtained by lixiviation.

Obs. In the above process the nitric acid appears to be formed by a combination of the nitrogen, which forms a part of all animal matters, and the oxygen of the atmosphore. Hence the necessity of a free circulation of air on the materials. The acid thus formed, unites to the potash of the vegetable materials which the heaps contain, and thus nitrate of potash is formed.

447. This salt is composed of nearly equal proportions of the alkali and the acid.

448. When submitted to a red heat, it is decomposed in consequence of the destruction of its acid.

Illus. By distilling nitre in an iron retort or gun barrel, oxygen gas is obtained in abundance. It is not perfectly pure, but sufficiently so for ordinary experiments.

449. This salt is rapidly decomposed by charcoal at a high temperature. It is also decomposed by sulphur.

Illus. Mix powdered nitre and sulphur, and throw the mixture, a little at a time into a red hot crucible. The sulphur will unite with the oxygen of the nitric acid, and form sulphuric acid. The potash being thus left free, there is formed a union between this and the new acid, and sulphate of potash remains in the crucible.

450. Nitre is the base of *gun powder*, *fulminating powder*, &c.

Illus. 1. A mixture of five parts powdered nitre, one part sulphur, and one of powdered charcoal composes gunpowder. The materials are first finely powdered separately, then mixed together, and beaten with a wooden pestle, a quantity of water being added to prevent an explosion. The mixture is afterwards granulated by passing it through sieves, and cautiously dried.

2. *Fulminating powder* is made by mixing three parts of powdered nitre, two of carbonate of potash, or common salts of tartar and one of sulphur. These ingredients must be carefully mixed by grinding them together in a mortar.

When a small quantity of this powder is gently heated nearly to redness on a shovel, or by other means, it explodes with violence, giving a loud and stunning report. Only 15, or 20 grains ought to be exploded at a time, within doors.

451. *Nitrate of Ammonia.* This salt is prepared by saturating dilute nitric acid with carbonate of ammonia.

Exp. Dilute some aqua-fortis with three, or four parts of water. Put this into a porcelain or earthern dish, and set it in a sand bath, or in hot ashes; then throw in pieces of carbonate of ammonia until it ceases to effervesce. Continue the evaporation until about two thirds of the solution is exhausted, or until a drop readily shoots into crystals on being placed on a piece of glass. Then set the dish aside until the crystals are formed.

Remark, If the solution is evaporated slowly, and with a gentle heat, and the vessel in which it crystalizes has a broad flat bottom, the crystals are very beautiful, long, shining, triated, prisms. If the solution is exhausted nearly to the point of crystalization while it remains hot, and this is done with a higher heat, it either shoots into small fibrous crystals, or concretes into a shapeless mass.

Obs. The most important property of this salt is its yielding, when decomposed by heat, the *nitrous oxide*.

MURIATES.

452. The muriates have a *saltish* taste, more or less pure. They emit white fumes when mixed with sulphuric acid. With nitric acid they emit oxymuriatic acid gas. They are all soluble in water, and with difficulty decomposed by heat.

453. *Muriate of Soda*. Common salt. Sea salt. Of all the saline substances this is the most common and abundant in nature. It is frequently found in extensive solid masses in the earth, or dissolved in springs and lakes far inland. The ocean, is however, the great depository of this salt, about a thirtieth of its weight being muriate of soda.

Illus. In Cheshire, England, there is a mine of this salt, whose beds are alternate with those of clay. The first bed of salt commences about 90 feet below the surface, and varies from 60 to 90 feet in thickness. Below this there is another bed whose thickness is not known, though it has already been penetrated to a great depth. The salt from this mine is carried to Liverpool where it is purified by solution in sea water, and by subsequent crystallization. Many thousand tons are annually shipped from that place, and hence it has acquired the name of *Liverpool salt*.

454. In Spain are many salt springs; and in Catalonia there is a mountain of rock salt, whose

height is estimated at 590 feet, and it is about three miles in circumference.

455. Common salt is also found in great abundance in Poland, Germany, Russia, and most other countries. In France are found many salt springs, but no mines.

456. In the desert of Lybia there is an immense plain covered with a crust of this salt.

457. In America there has already been discovered many localities of common salt, either in a solid state or dissolved in springs of water.

458. In Peru are numerous salt mines situated at a great elevation above the sea. It has also been found in Chili, Calafornia, St. Domingo, &c.

459. In the United States, salt springs are numerous in several districts. These springs sometimes flow naturally, but are more frequently formed by sinking wells into those places where this salt is known to exist. Most of these springs are west of the Allegany mountains; but in the state of New-York, there are several in the vicinity of the Cayuga and Onondaga lakes.

Obs. From many of these springs salt is obtained by evaporating the waters, either by boiling or by exposure to the sun in shallow vats.

Illus. It is estimated that the whole quantity of salt extracted from saline springs in the United States, exceeds six hundred thousand bushels. Of this, the springs at Onondaga and Cayuga furnish about three hundred thousand bushels.

460. Muriate of soda is also extracted from sea water, by heat or exposure to the air and sun. During our revolution, considerable quantities were prepared by the former method in this country.

Obs. 1. This salt crystalizes in regular cubes. It requires for its solution, twice and a half its weight of water at the temperature of 60 degrees.

2. When heated gradually, it fuses, and forms when cold a solid compact mass. When mixed with charcoal or sulphur, and ignited in a crucible, it is not decomposed, nor does it undergo any change.

3. It is decomposed by sulphuric acid in consequence of the strong affinity of the latter for the soda which it contains.

4. It is on this principle that muriatic acid is obtained.

5. Muriate of soda, is composed of acid 46 and soda 54=100.

Muriate of Ammonia. See Ammonia.

461. *Muriate of lime.* To prepare this salt, saturate with pure white marble any quantity of muriatic acid, diluted with two or three parts of water. Then evaporate the solution and set it away to crystallize.

Obs. This salt absorbs water with such extreme avidity, as to effect its own solution in a short time when exposed to the air.

It is composed of nearly equal parts of acid and base, and 25 per cent. of water.

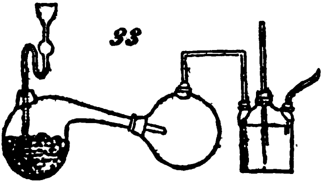
OXYMURIATES.

Remark. These salts have lately been called *Chlorates* and *Hyper Oxymuriates.* We shall call them Chlorates.

462. The Chlorates give out very pure oxygen gas when submitted to heat, and turn to muriates. They inflame some combustible substance spontaneously, and with violent detonations.

463. *Chlorate of Potash.* This salt is prepared by passing chlorine gas through a solution of caustic potash.

Exp. 1. Grind together in a mortar four ounces of common salt and one ounce and a half of black oxide of manganese, and put the mixture into a stoppered retort. Connect with the retort a balloon, as in fig. 33, and from the balloon let a bent glass tube pass into a three necked bottle, filled with a strong solution of caustic potash, so as nearly to reach the bottom. After every thing is arranged as in the figure, and the junctures are made tight, pour into the retort through the safety



tube two ounces of sulphuric acid, diluted with an equal quantity of water. Then apply to the retort the gentle heat of a lamp. Or,

Exp. 2. Introduce into the retort four ounces of muriatic acid and two ounces of finely powdered black oxide of manganese, and proceed exactly as above.

Obs. The Chlorine gas which is formed by either of the above experiments passes into the solution, where it combines with the potash. When this is saturated, the gas will pass off at the bent tube. To obtain the salt evaporate the solution gently and on cooling it will deposite small shining crystals. These are chlorate of potash. The first product only must be reserved for use, as after this, the crystals are merely muriate of potash.

Caution. Care must be taken not to let any of the Chlorine escape into the room. Violent coughing, and even death has been produced by breathing this gas.

464. When chlorate of potash is submitted to distillation in a coated glass retort, it first fuses, and on a further increase of temperature yields oxygen gas of great purity.

465. This salt alone has no power in discharging colours, but by the addition of a little sulphuric acid, the chlorine is set free, and vegetable colours are destroyed by it.

466. When mixed or rubbed with inflammable substances it effects their combustion with more or less rapidity.

Exp. 1. Rub two grains of chlorate of potash in a mortar, and add one grain of sulphur. Mix them accurately by gentle trituration, and having collected the mixture to one part of the mortar, press the pestle down upon it suddenly and forcibly. A loud detonation will ensue.

467. If the same mixture be wrapped in some strong paper, and then struck with a hammer, a still louder report will be produced.

2. Mix in a mortar five grains of the salt with half the quantity of powdered charcoal. On rubbing the mixture strongly with a pestle it will inflame.

3. Mix a small quantity of sugar with half its weight of the

salt, and on the mixture pour a little strong sulphuric acid. A sudden and vehement inflammation will be produced.

Obs. The red French matches are prepared on the above principle. Having finely powdered some of the salt separately, mix it with double its weight of white sugar, moistened, so as to make it into a paste and at the same time to prevent explosion. Then dip common brimstone matches in the paste and let them dry. The bottle into which they are dipped contains strong sulphuric acid, which is prevented from escaping by a quantity of finely spun glass, or some fibres of asbestos. To light one of these matches, it is only necessary to dip it into the bottle.

Expl. The chlorine of the chlorate of potash being set free, by the stronger affinity of the sulphuric acid for its base, accension takes place in consequence of the action of the chlorine on the hydrogen and carbon of the sugar.

In the above instances, where mixtures of this salt and combustibles are inflamed by friction, or percussion, the chlorine is extricated by the heat caused by the friction, or percussion.

Exp. 4. To one grain of the powdered salt in a mortar, add about half a grain of phosphorus and rub them together with the pestle. Very violent detonations will be produced, attended with vivid flashes of light.

Caution. The hand which holds the pestle should be covered and the face averted, as the inflamed phosphorus sometimes flies several feet.

Exp. 5. Put into a wine glass ten or twelve grains of the salt, and two or three of phosphorus, and fill it nearly with water. Then by means of a glass tube reaching the bottom, pour in a dram or two of sulphuric acid. The phosphorus will take fire and burn vividly under water.

Expl. The sulphuric acid, at the same time it heats the phosphorus by raising the temperature of the water, and thus prepares it for combustion, extricates the chlorine from the potash, by which the combustion is supported.

468. Chlorate of potash may be used in the preparation of gunpowder, as a substitute for nitre; but the mixture of the ingredients requires extreme circumspection, as they sometimes explode to the great danger of the operator.

Caution. Mixtures of this salt with sulphur sometimes explode spontaneously. All experiments with it should be made with great care, and only in small quantities.

CARBONATES.

469. The carbonates of the alkalies, always preserve more or less their alkaline properties. These salts are decomposed by any of the strong acids, occasioning a brisk effervescence, owing to the escape of carbonic acid. The carbonates of the metals very much resemble their oxides.

470. *Carbonate of lime.* Nature furnishes this salt in great abundance. What are called *calcareous* minerals, as limestone, marble, one kind of alabaster, marl, chalk, &c. are more or less carbonates of lime.

471. The carbonate of lime is soluble in the nitric, sulphuric, or muriatic acids. During the solution there is a brisk effervescence, occasioned by the escape of carbonic acid.

472. By a strong heat the carbonic acid is driven off, and quicklime remains.

Illus. Lime, or quicklime, the article used in making mortar, is prepared by submitting limestone to a strong heat in kilns, erected for that purpose. The carbonic acid being by this means expelled, there remains a substance, which instead of being mild and inert as before, has now become extremely caustic, destroying both animal and vegetable substances.

Obs. Lime has a strong affinity for carbonic acid, from which it is separated only by an intense heat, or by an acid stronger than the carbonic. In the state of carbonate of lime, therefore, it does not act on other substances.

473. Carbonate of lime is decomposed by the stronger acids, the carbonic acid being set free, while a new salt is formed.

Exp. Put some powdered chalk or marble into a vessel, and pour on it some sulphuric acid, diluted with five or six times its bulk of water. A violent effervescence will be occasioned in consequence of the escape of carbonic acid. At the end of the experiment, *sulphate of lime* will be found to have taken the place of the carbonate.

474. Lime absorbs carbonic acid from the atmosphere.

Illus. Leave a shallow dish of lime water exposed to the air. In a few days a white crust will be formed on the surface, which if broken will fall to the bottom, but will be succeeded by another. These crusts are carbonate of lime.

475. Carbonate of lime, though scarcely soluble in pure water, is considerably so in water containing carbonic acid.

Exp. Add to a jar about one fourth filled with lime water, a very small quantity of water saturated with carbonic acid. An immediate milkiness will ensue, because the carbonic acid forms with the lime an insoluble carbonate. Add gradually, more of the water impregnated with carbonic acid, shaking the jar as these additions are made. At last the precipitate will be redissolved. Hence it appears that lime, with a certain proportion of carbonic acid, is insoluble, but with a larger proportion it is soluble.

476. *Carbonate of potash.* This is the common *potash*, or as it is called *pearlash.—For an account of its preparation, &c. see potash.*

477. Carbonic acid is absorbed in great abundance by *pure* potash.

Illus. Fill a common vial with carbonic acid gas over water, and stop it with the thumb. Then invert the vial in a solution of pure potash contained in a cup, and rather exceeding in quantity what is sufficient to fill the bottle. The solution will rise in the vial, and if the gas be pure, will fill it entirely. Pour out the alkaline liquor, and again fill the vial with the gas and proceed as before. In this way it will be found that the alkali is capable of absorbing several times its bulk of carbonic acid.

In consequence of the absorption of the carbonic acid, remarkable changes are effected on the properties of the potash.

Illus. After absorption of the acid, the potash will be found to have lost much of its corrosive and penetrating taste. It no longer destroys the texture of woollen cloth, but still turns to green the blue infusions of vegetables. Before its absorption of this gas, nothing remarkable ensued on mixing it with dilute sulphuric acid, but if this, or almost any other acid be now added, a violent effervescence will ensue, arising from the escape of the gas that had been previously absorbed.

478. The potash, and pearlash of commerce are *sub-carbonates* of potash of different degrees of purity. The quantity of carbonic acid contained in these alkalies may be learned by a very simple experiment.

Exp. Put one or two hundred grains of the alkali into a Florence flask and add a few ounces of water. Take a vial filled with dilute sulphuric acid, and place this as well as the flask in one scale. Balance the two by putting weights into the opposite scale, and when the equilibrium is exactly attained, pour the acid into the flask of alkali till the effervescence ceases. As the gas makes its escape the side containing the weights will gradually sink, and the addition of weights to the other side of the scale will show the amount of loss

The sub-carbonate, or common potash, contains about 30 parts of acid to 70 of the alkali, to the 100.

479. *Bi-carbonate* of Potash. Common potash may be fully saturated with carbonic acid by the following process.

Exp. To a filtered solution of four pounds of pearlash in four quarts of water, add one pound of carbonate of ammonia, reduced to powder; and stir the mixture at intervals, till the carbonate of ammonia is entirely dissolved. Filter the liquor, and put it into a retort, connected with a receiver and distil off with a very gentle heat about half a pint of the liquor, which will be a solution of carbonate of ammonia in water. The solution may then be transferred from the retort into an evaporating dish. When cold, crystals of the bi-carbonate of potash will be formed. If, however, the crystals do not shoot, the liquor must again be put into the retort, and the distillation repeated. After the first crop of crystals are formed, these must be collected and the liquor distilled again, when on cooling, more will form, and this will be the case several times. There will however be a part of the solution which will not crystallize. This may be boiled to dryness and applied to the ordinary purposes of carbonate of potash.

Bi-carbonate of potash contains about 44 parts of acid, 48 of base and 8 parts of water to the 100.

480. *Carbouate of Soda.* This is the common soda. The mode of procuring it has already been detailed.

Obs. There are two distinct compounds of carbonic acid and soda, one of which contains precisely twice as much carbonic acid as the other.

The *sub-carbonate,* which is the common soda of commerce, contains in 100 parts, acid 13.98, base 23.33, water 62.69=100.

The *bi-carbonate* is obtained by saturating the sub-carbonate, which is done by passing a stream of carbonic acid through its solution, or by exposing the dry salt to the action of the gas in a fermenting vat.

The bi-carbonate has a milder taste than the sub-carbonate and requires a larger quantity of water for solution. By exposure to a red heat the whole of its water and about half of its carbonic acid is expelled.

Bi-carbonate of Soda contains to every 100 parts, acid 49, base 37, and water 14=100.

COMPOUND COMBUSTIBLE GASES.

Remark. A table of the gases will be found at page 57. Those with simple bases have been noticed with the *simple substances,* and several of the compound gases it was thought best to describe in connection with the articles which formed their bases.

CARBURETTED HYDROGEN.

481. This gas is composed of carbon and hydrogen. There seems to be several varieties of it, differing in the proportions in which the two substances unite, and consequently in weight and splendor of burning. It is chiefly procured by the distillation of *mineral coal,* but may also be obtained from *charcoal* and *water* by passing the steam of the latter through a tube containing the former at a red heat; from *alcohol* or *ether* by passing either of them in the state of vapor, through a red hot porcelain tube; from *sulphuric acid* and *alcohol* by distilling them together in a retort; and by stirring up the mud in *stagnant ditches* of water.

These gases all agree in being inflammable, but differ greatly in respect to the quantity of light which they emit during combustion.

482. The specific gravity of each of these gases, depends on the relative proportions of carbon and hydrogen of which it is composed. The brilliancy with which they burn is also dependent on the same circumstance.

Thus, the specific gravity of that obtained from *moistened charcoal* is only 480, air being 1000, and it burns with a faint blue light not at all fitted to the purpose of illumination; that from *mineral coal* when fresh prepared is about 780, and it burns with a brilliant white light; that from *alcohol* and *sulphuric acid* has a specific gravity about 950, and greatly surpasses all the others in quantity of light which it evolves by combustion.

Obs. In England, carburetted hydrogen is used for the purpose of lighting streets, houses, factories, &c. For this purpose it is procured by the distillation of mineral coal. The distillation is carried on in large iron retorts, and the gas being first passed through a cistern of lime water to purify it, is then carried in iron pipes wherever it is wanted. The pressure which forces the gas along the pipes, and out at the orifices where it is burned, is made by means of water, contained in a vessel of a peculiar construction, called a *gas holder*. Wherever a light is required, a small tube proceeds from the main one, which is furnished with a stop-cock and pierced with a fine orifice, at which the gas is lighted.

When a light is wanted, all one has to do is to turn the stop-cock and hold a candle to the orifice. To extinguish it, the stop-cock is again turned so as to exclude the gas from the orifice.

To make experiments on coal gas, procure a pistol barrel, or piece of gun barrel stopped at one end, which may be done with a lute made of clay and sand. About half fill the barrel with mineral coal in coarse powder, and pass it through a small furnace, or chaffing dish of charcoal, so as to heat it red hot.

Connect with the open end of the barrel a tube of lead, tin, or glass, leading under a vessel inverted, and filled with lime water. For this part of the apparatus, two small kegs, both of them open at one end, will answer very well. Fill the largest of them with lime water, and having furnished the other with a stop-cock passing through the head, invert this into the other, and on opening the stop-cock so as to let off the air, it will sink down and fill with water. When it is full and all the air is forced out, turn the stop-cock and then having passed the tube which conveys the gas under it, make a fire in the furnace so as to heat the gun barrel red hot. The gas will soon be driven off in abundance.

To burn it, a piece of lead, tin, or brass tube may be fastened to the stop-cock by soldering, or by means of melted bees wax and a strip of rag. The upper end of this tube being closed, make two or three fine orifices about the size of pin holes around the tube. On turning the stop-cock and applying a lamp, the gas will burn with a beautiful white flame, the sight of which will amply repay the young chemist for the trouble of making the experiment.

To obtain carburetted hydrogen from alcohol by means of sulphuric acid, mix together in a tubulated retort, one measure of alcohol and three measures of the acid. The alcohol is to be poured in first, and the acid mixed with it a little at a time, as a great degree of heat would be the consequence of mixing them suddenly. Connect with the retort a tube leading under the vessel, as described for obtaining the coal gas, and distil with a gentle heat.

This gas exceeds all others in the splendour and beauty of its flame.

OXIDES IN THE STATE OF GAS.

CARBONIC OXIDE.

483. This is also called *gaseous oxide of carbon.* It contains a less quantity of oxygen than carbonic acid, but is composed of the same elements.

484. Carbonic oxide is obtained by exposing carbonic acid to the action of some substance, which has the power of abstracting a part of its oxygen. This may be done by heating in an earthen retort or iron bottle, a mixture of equal parts of *chalk* and *charcoal.* Or by heating in the same way, equal parts of *chalk* and *iron filings.*

Obs. In both of these experiments the result is the same. The carbonic acid being expelled from the chalk by the heat, the charcoal or iron filings having a strong attraction for oxygen, absorbs a portion from the carbonic *acid*, and the consequence is, that carbonic *oxide* is formed; or in other words, the carbonic *acid* is changed into carbonic *oxide* by the loss of a portion of oxygen.

485. This gas may be received over water in the usual way, but if it is required in a state of purity, lime water must be used. The last product of the distillation is the purest gas.

486. This gas is lighter than common air. It is inflamable when fired from a small orifice, and burns with a blue flame.

487. When burned in the manner which proves that hydrogen forms water by combustion, no water is formed which proves that it contains no hydrogen.

Obs. It is extremely noxious to animals, and fatal to them if confined in it.

NITROUS OXIDE.

488. This compound gas is composed of oxygen, and nitrogen.

It may be obtained by several processes; but that of distilling the *nitrate of ammonia* is the only one which affords it in sufficient purity for respiration. For the method of making this salt, see *nitrate of ammonia.*

Exp. To prepare this gas and try its effects by respiration, the following simple apparatus may be used where no better can be obtained. Prepare a Florence flask by fitting to it a tube as in figure 6. Into this put two or three ounces of nitrate of ammonia. For a gas holder, fit to a large stone jug a cork pierced with two apertures by a burning iron. Into one of the apertures pass a tube of glass or tin, so that it shall come within half an inch of the bottom of the jug when the cork is put in its place; and let the other orifice be stopped with another cork.

For a pneumatic tub, take a common wash tub, and fit to it a strip of board passing through the middle, and about three inches from the top, so that when the tub is filled with water the board will be covered. The board must have a hole through it. over which the mouth of the jug is to be set.

Having prepared things as above directed, fill the jug with water and invert it over the aperture of the board ; bend the tube belonging to the flask so that it will just enter the mouth of the jug, and setting the flask on the lamp stand, apply a very gentle heat. If there is no lamp furnace at hand, the flask can be suspended by a string or wire, and heated by a common lamp, or two. The salt will soon melt and become fluid, and the gas will be extricated in abundance. When the jug is nearly full, which can be told by the noise of the bubbles, slip the hand under its mouth and set it upright ; then immediately put the cork with the tube through it in its place.

Having prepared the gas, let it stand over the water which remains in the jug for an hour or two, shaking it now and then, so that if it should contain any nitrous gas, this may be absorbed.

To respire the gas, prepare a bladder, or oiled silk bag, by attaching to it a tube which exactly fits the second aperture in the cork, and having squeezed all the air out of the bladder, or bag, pass in the tube.

Next pour such a quantity of water into the jug through the long tube, as you wish to obtain of the gas. It is obvious that the gas cannot escape through the long tube, because its lower end is immersed in the water. It is therefore forced into the bladder. When this is full, withdraw the tube from the jug, and holding the nose with one hand, with the other apply the tube to the lips, and respire it backward and forwards from the bladder to the lungs.

The lungs must first be exhausted of air by breathing *out* before the gas is inspired. The quantity to be breathed is from two to four, or even eight quarts.

OF VEGETATION.

489. Notwithstanding the great variety of forms, textures, and colours, under which plants and their several parts, as seeds, fruit, &c. appear, their chemical properties differ only in being composed of various proportions of the same principles, *oxygen*, *hydrogen*, and *carbon*, being the principle constituents of all vegetables, to which is occasionally added small proportions of nitrogen. The vari-

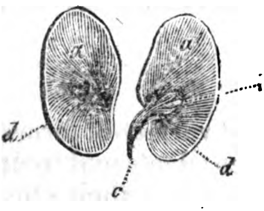
ous proportions in which these elements are combined, together with the mode of combination, causes the great diversity which subsists among the products of the vegetable kingdom.

490. The essential organs of plants are the *root*, the *stem*, the *leaves*, the *flowers*, and the *seeds*.

Obs. The *root* serves to attach the plant to the soil, and is one of its organs of nutriment. The *stem* is usually erect and subdivided into branches which bear the *leaves* and *flowers*, and upon which the *fruit* or *seeds* are ultimately produced.

491. When a seed is placed under certain circumstances, favourable to its growth, it soon undergoes a change. It swells, grows soft, bursts its membrane or shell, and at the same time from being insipid and farinaceous, it becomes sweet and mucilaginous, and serves for the nutriment of the young plant. The stem and leaves are soon after elevated above the surface of the earth, in search of air and light, while the roots shoot downwards, or spread about under its surface, to obtain a further supply of nourishment.

492. The seed, however various in form, consists essentially of the *cotyledon*, the *plume*, and the *radicle*.



Obs. The cotyledon contains the matter necessary for the early nutrition of the young plant. Sometimes it is single, sometimes double, and semetimes divisible into lobes.

The plume afterwards produces the stem and leaves, and is enveloped by the cotyledons; the radicle becomes the root.

All these parts are well seen in the garden bean. See the fig. where *a a*, are the cotyledons; *b* the plumula; *c* the radicle, and *d. d.* the external membrane.

Obs. The circumstances requisite for the healthy germination, or growth of seeds, are principally the following.

1. A due temperature, which is always above the freezing point, and below 100 degrees.

2. Moisture in a certain proportion, depends on the kind of seed.

3. A proper access of air, the oxygen of which is slowly converted into carbonic acid. The joint operation of all these agents is necessary; for seeds exposed to air and moisture, the temperature being below 32 degrees, will not grow, though they are not absolutely destroyed by the frost. Nor will a seed vegetate without air though heat and moisture be present. This is shown by burying seeds deep in the earth, and by the spontaneous vegetation upon soil newly turned up and exposed to the air. Thus a specimen of alluvial soil on being exposed to the air will afford grass, from the seeds it already contained, and which have been for years in a torpid state for want of oxygen.

This curious fact is further proved by exposing seeds to proper degrees of heat and moisture, but contained in the exhausted receiver of an air pump. Mr. Ray, found that seeds so placed, could not be made to germinate, but began to grow as soon as the air was admitted.

493. Seeds do not germinate unless *oxygen* be present.

Illus. It has been proved by the most careful experiments, that oxygen gas is absolutely necessary to the germination of seeds, and that no seed will grow in nitrogen gas, hydrogen gas, or in carbonic acid, when these gases are pure, or contain no oxygen. It follows therefore, that it is not the whole atmosphere, but only the oxygen gas which it contains, that is necessary to the germination of plants.

It appears however, that only a very small quantity of oxygen is necessary to effect the germinating process, for it is found that if the receiver of the air pump in which the experiment is made, is not completely exhausted, these seeds will sprout, and by not producing a complete vacuum, several philosophers have been deceived, and have concluded that air was not absolutely requisite to germination. The growth of seeds when buried to a certain depth in the earth, also shows that very little oxygen is necessary.

494. When the plant is elevated above the soil, and shoots forth leaves, it obtains nourishment from the air as well as from the earth.

Obs. The immediate source from which plants obtain their food, has been a matter of doubt and controversy. It is certain however that they will not grow, unless heat, air, and moisture be present at the same time. It also seems requisite for their vigorous growth, that their roots should be placed in the earth; but whether the earth contributes to their nourishment, or serves merely to give them support, was a question which for a long time remained undecided.

Van Helmont planted a willow which weighed 5 pounds in a pot containing 200 pounds of earth. This he watered for the space of five years, and at the end of that time the tree was found to weigh 169 1-4 pounds, while the earth being dried was found to have lost only two ounces of its original weight. Here then was an increase of 164 pounds and yet the only food of the plant was water.

This experiment was supposed to settle the question that pure water was the sole food of plants, until it was afterwards shown, that the water with which the plant was moistened, contained as much earth as could exist in the willow at the end of the five years.

495. After a great variety of experiments on this subject it has been ascertained that plants will germinate in pure water, and that the young plant will for a time grow with no other aliment, but that it soon becomes unhealthy, and does not come to maturity and produce seed without other nourishment.

496. It has also been demonstrated, that plants absorb something from the soil on which they grow besides water, for on their analysis they are found to contain a quantity of earth, which is of the same kind with the soil on which they stand.

497. Another proof that plants require something besides water, is afforded by the fact that soils become sterile by a long succession of crops, but are again made productive by manure.

498. It is not however the *earths* contained in a soil which makes it productive, but the remains of animal and vegetable substances, and the proportion of these capable of being held in solution by water.

Illus. On making an experiment by planting some vegetables in the pure earths, as silica, alumine, magnesia, &c. and moistening them with pure water, it was found that they could not be made to grow, but on moistening the earths with some water from a manure heap the plants grew well.

Obs. It is well known that earth alone, such as is dug up at a considerable depth from the surface of the ground does not form a productive soil, but that a good soil always contains a greater or less proportion of vegetable mould: and it is most probable that this, which is formed chiefly of decayed vegetables, is absolutely necessary to the growth of plants. Its solubility in water probably prepares it for absorption by the roots of the vegetable, after which, by some unknown process it is first converted into sap, and afterwards becomes a part of the plant itself.

499. As the roots of plants contain no visible openings, the food which they imbibe from the earth must be in a state of solution, and is distributed to all parts of the plant, by means of the sap of which it forms an ingredient.

Obs. The sap which may be considered as the *lymph* of the plant, is, during vegetation, constantly ascending from the root towards the summit, and ultimately into the leaves. Here it undergoes a considerable change; the watery parts being thrown off by the perspiration of the leaves, while that which remains is converted into a peculiar juice, called the *true sap*, which like the blood of animals, is afterwards employed in forming the various substances found in plants.

500. The leaves of plants are not only their perspiratory organs, but they also perform the office of absorbing the carbonic acid gas from the atmosphere.

Illus. 1. The leaves of plants throw off large quantities of moisture by perspiration. This process is constantly going on so long as the plant is growing, but is much greater in the day time than during the night. Dr. Hales found, that a cabbage transmitted daily a quantity of moisture nearly equal to half its weight. The office of transpiration is performed by the upper surfaces of the leaves only, and may be almost entirely stopped by varnishing that surface.

2. The fact that plants absorb carbonic acid, was first discovered by Dr. Priestly. He found, on making a sprig of mint vegetate for ten days, in a portion of this gas, which would instantly extinguish a candle, that at the end of that time, the can-

dle would burn in it perfectly well. Subsequent experiments have shown, that plants will not vegetate in pure carbonic acid, but that a certain quantity not only improved their growth, but is absolutely necessary to healthy vegetation.

501. While plants absorb carbonic acid they give out oxygen gas.

Illus. It is well known, that on exposing a sprig of mint or any other plant of vigorous growth, to the action of the sun, that it gives out oxygen gas. For this purpose the plant is placed in an inverted bell-glass filled with water. When a plant thus situated is exposed to the direct rays of the sun, the leaves are soon covered with small bubbles of the gas, which rise up, displace the water, and fill the upper part of the vessel.

502. Carbonic acid is decomposed by the organs of growing plants, the carbonic being retained, while the oxygen is given out.

Illus. It has already been stated, that when a sprig of mint, or other plant, is exposed to the direct rays of the sun in a glass of water, that it emits oxygen gas. Now the vessel and water only serve as the means of ascertaining this fact, the vessel to retain the gas, and the water to exclude the air, the water and plant having no action on each other, by which such an effect is produced.

503. The oxygen gas which plants give out when confined in water, is obtained from the carbonic acid which it absorbs from the air contained in the water.

Illus. For when the experiment is made with water which has been boiled, or has had the air exhausted from it by means of an air pump, not a particle of oxygen is obtained.

2. Another proof that vegetables absorb carbonic acid, and in consequence emit oxygen gas, is, that they do not give out the latter unless the former be present.

Corol. Thus, then, plants absorb carbonic acid, retain the carbon for their own nourishment, but return the oxygen; and it is most probable, that the carbon which trees and other plants contain, and which forms the greatest part of their bulk, is obtained from the atmosphere, by the absorption and decomposition of carbonic acid gas.

504. Plants will not vegetate unless oxygen gas or atmospheric air be present.

Illus. It has been found that carbonic acid, nitrogen, or hydrogen, when pure, would destroy plants altogether; but that when mixed with a small proportion of oxygen or atmospheric air, vegetation went on well in either of these gases.

505. Plants *absorb* oxygen gas, and while this process is going on they *emit* carbonic acid.

Illus. When the leaves of plants are placed in contact with a confined portion of atmospheric air during the night, the air is found in the morning to be diminished in bulk, and to have lost its oxygen; at the same time a portion of carbonic acid is found instead of the oxygen absorbed.

Remark. The pupil will remember that this is the reverse of what has been stated on another page; both propositions are however true.

506. During the night plants absorb oxygen and form with it carbonic acid, a portion of which they transmit, but not all.

Obs. Plants will not live without this nightly inspiration of oxygen, even though supplied with carbonic acid, provided the oxygen formed by them during the day, is constantly withdrawn from them at the approach of night.

507. The leaves of plants absorb water as well as oxygen and carbonic acid.

Illus. The great effect which dew and light showers, or even wetting the leaves of plants have in reviving their strength and making them grow when they are drooping with heat and drought, are so many proofs that the leaves imbibe moisture from the atmosphere.

508. Experiments have shown that leaves continue to live for weeks, when one of their surfaces is applied to water, and that they not only vegetate themselves, but even imbibe water enough to support the vegetation of a whole plant, and the leaves belonging to it.

509. It is most probable then that during dry seasons, when there is a defect of moisture in the earth, and consequently an insufficient absorption by the roots, that the plant is in part supplied by

imbibing it from the atmosphere, or from the dew which falls on it during the night.

Corol. Thus it appears that *water*, *carbonic acid* and *oxygen*, are each of them absorbed by the leaves of plants at one time, and emitted by them at another.

510. In addition to heat, moisture, and oxygen, healthy vegetation requires the action of a certain quantity of *light*.

Illus. Plants growing in the dark are white, or nearly colourless; hence, the green colour of all vegetables depend on the light.

511. The disposition of plants to enjoy the light is expressed by their inclination towards it, when it is stronger in one direction than in another.

Illus. Thus potatoes or bean vines growing in a dark cellar, will always run towards a part where there is the most light, and if possible will creep out into the open air.

512. Plants growing in flower pots placed in a window, turn the discs of their flowers and leaves towards the light and grow in that position.

513. In thick forests the trees grow tall for the same reason; they stretch up to enjoy light and heat.

514. Plants growing in the dark, contain less carbonaceous matter and more water than those which vegetate in the usual manner.

Illus. A plant which grew in the dark was found to contain only about one ninetieth part of carbon; but on permitting the same plant to grow for thirty days in the sun it was found to contain one twenty-fourth part of carbon.

515. Plants vegetating in the dark contain less hydrogen and more oxygen, than those which grow in the light.

Illus. It has been found that no oxygen is emitted by such plants as grow in the dark, and as the emission of oxygen is owing to the absorption of carbonic acid, it is probable that this is not absorbed. This then, would account for the small quantity of carbonaceous matter, which such plants contain as well as for the reason why they do not give out oxygen.

Obs. The quantity of oily matter in etiolated plants is very small. Oil is composed chiefly of carbon and hydrogen. Hence the formation of oil probably requires the agency of its light.

516. RECAPITULATION. Vegetable substances are chiefly composed of *carbon*, *ogxyen*, and *hydrogen*, but occasionally contain a portion of *nitrogen*.

517. During the process of germination, the farinaceous substance of seeds becomes sweet, and affords nourishment to the young plant.

518. Healthy germination does not take place without heat, oxygen, and moisture.

519. Seeds will not germinate in the exhausted receiver of an air-pump, though heat and moisture be present.

520. Plants receive nourishment from the air, as well as from the earth.

521. Plants nourished by pure water alone, but having access to air, grow for a time, but will not produce seeds.

522. It is most probable that all the food which vegetables receive by their roots, is in a state of solution in water.

523. The sap undergoes a great change in the leaves, where it loses a portion of water, and is converted into *true sap*, which afterwards goes to form the various substances found in plants.

524. Plants absorb carbonic acid and at the same time give out oxygen gas.

525. Plants absorb oxygen gas and give out carbonic acid.

Obs. It appears that the leaves of plants perform very different operations at the different periods of 24 hours. During the *day* they are giving out moisture, absorbing carbonic acid, and emitting oxygen gas; during the *night*, on the contrary, they are absorbing moisture, giving out carbonic acid gas, and absorbing oxygen gas.

526. Plants do not live without they are permitted to absorb oxygen during the night. Nor do they live without the absorption of a quantity of carbonic acid during the day.

527. Vegetation will continue for a time in carbonic acid, or in oxygen gas, because when confined in the *carbonic acid* it emits during the *day* a quantity of *axygen* which it again absorbs at *night*, and when confined in *oxygen* it gives out a portion of *carbonic acid* at *night*, which again serves it during the day.

Corol. We may then conclude that plants obtain their food from the *earth*, from *water*, and from the *atmosphere*. From the earth they take up a small quantity of earthy matter. From water they obtain nourishment in consequence of its holding in solution decomposed vegetable matter. And from the air they absorb carbonic acid, emit the oxygen, but retain the carbon, which forms the principal part of their bulk.

528. Healthy vegetation absolutely requires the agency of *light*.

529. Plants growing in the dark are white. They show their propensity to enjoy the light by leaning or creeping towards it.

Etiolated plants contain less carbon and hydrogen, but more oxygen, than others. They do not absorb carbonic acid gas. They contain a deficiency of oily matter.

OF THE COMPOSITION AND ANALYSIS OF VEGETABLE SUBSTANCES.

530. When vegetable substances are submitted to destructive distillation, the carbon, hydrogen, and oxygen, enter into new combinations, and we obtain a variety of *products*, differing according to the nature of the vegetable and the mode of distillation.

Obs. In general the products of vegetables treated by distillation are, *water, pyroligenous acid, empyreumatic oil, carbonic acid*, and *carburetted hydrogen.* If the vegetable contains *nitrogen*, a quantity of ammonia is obtained. A portion of charcoal, with a small quantity of earthy and saline matter, remains in the retort.

531. These several products are all composed of the same ultimate principles, but combined in different proportions and newly arranged.

Illus. Water is composed of *oxygen* and *hydrogen.*

Pyroligneous acid consists of *oxygen, hydrogen*, and a small quantity of *carbon.* The oxygen being in such a proportion as to give the acid properties.

Empyreumatic oil is chiefly composed of *carbon* and *hydrogen*, but contains also a small portion of *oxygen.*

Carbonic acid consists of *carbon* and *oxygen.*

Carburetted hydrogen is composed entirely of *carbon* and *hydrogen.*

Ammonia consists of *nitrogen* and *hydrogen.*

These several products being separately submitted to analysis, will show the proportions of carbon, hydrogen, oxygen, and nitrogen which each contains.

532. By subjecting different vegetable substances to ultimate analysis, it has been ascertained that the products which result from the different combinations of oxygen and hydrogen, are as follows:

A vegetable substance is always acid where the oxygen which it contains is to the hydrogen in a proportion greater than is necessary to form water, or where there is *excess of oxygen.*

A vegetable substance is resinous, oily, or alcoholic, where the oxygen is to the hydrogen, in a less proportion than in water, or where there is *excess of hydrogen.*

A vegetable substance is neither acid nor resinous, but saccharine, mulcilaginous, &c. where the oxygen and hydrogen are in the same relative proportion as in water, or where there is *no excess of either.*

Obs. In addition to the oxygen and hydrogen, there is in resin, oil, alcohol, sugar, and mulcilage, a quantity of carbon.

OF THE INGREDIENTS OF PLANTS.

533. The *ingredients* of plants are distinct sub-

stances, formed by their secreting organs, and separable from each other without destructive distillation.

534. They are separated by certain solvents which have the power of dissolving some, but not the others. Thus water dissolves gum, but not resin; while alcohol will take up the resin and leave the gum, &c.

Obs. The solvents made use of for separating the ingredients of vegetables, are hot and cold water, alcohol, ether, and some of the acids.

2. The following are the principal ingredients, or what are called the *proximate* principles of vegetables. Some account of the most important among them will be given.

1. Gum.
2. Sugar.
3. Starch.
4. Gluten.
5. Extractive and Lignum.
6. Tannin.
7. Colouring matter,
8. Wax.
2. Fixed oil.
10. Volatile oil.
11. Camphor.
12. Resins.
13. Narcotic principle.
14. Bituminous substances.
15. Vegetable acids.

535. Gum. *Gum Arabic* may be taken as a specimen of pure gum. It dissolves in water forming a viscid solution, or *mucilage* from which it may be obtained in its original state by evaporation. It is insoluble in alcohol, which therefore causes a white precipitate in its aqueous solution.

Obs. 1. Gum is decomposed by sulphuric and nitric acids: the former produces water, acetous acid, and charcoal; the latter among other products converts a portion of the gum into a white acid substance, called *mucous acid*.

2. When gum is submitted to destructive distillation it affords carbonic acid, and carburetted hydrogen, empyreumatic oil, water, and a quantity of impure acetic acid.

536. Sugar. Sugar may be extracted from a number of vegetables, and several roots, but is chiefly obtained from the sugar cane, a plant which thrives in hot climates. The juice of this plant is

expressed and evaporated with the addition of a small quantity of lime, until it acquires a thick consistency; it is then transferred into wooden coolers, where a portion concretes into a crystalline mass which is drained, and then forms what is called *muscovado* or *raw sugar*. The liquor which is drained off is called *molasses*.

Obs. Raw sugar is purified by the following process. It is dissolved in water mixed with lime and bullock's blood. This composition is agitated to mix the blood and water well together. The use of the lime is to mix with the molasses and render it more soluble, and consequently to facilitate its separation from the sugar. This operation is done in pans, under which a fire is now kindled, and when the liquor begins to boil, the albumen of the blood coagulates, rising to the top and bringing with it such impurities as the sugar contained The liquor being kept gently simmering, the impurities are constantly rising to the surface, from whence they are removed by a skimmer.

When the solution is judged to be sufficiently clear, it is placed in smaller pans and boiled rapidly until it becomes so thick as that a small quantity being placed on the thumb, may be drawn in threads by the fore finger. It is then passed into coolers, where it is agitated with wooden oars, until it appears thick and granulated.

It is said by Mr. Brande, that it is on this agitation in the cooler that its whiteness and fineness of grain in the refined sugar depends. The crystals being broken by the agitation, and the whole converted into a granular mass, facilitates the draining off of the coloured liquid.

After this it is placed in conical cups of earthen ware, of the well known form, called *sugar loaf*. These moulds have apertures at the bottom, to which stoppers are fitted. After the sugar is placed in them, and has become cold, the stoppers are removed and the loaves are allowed to remain in them until another portion of molasses drains off, which leaves the sugar much whiter than before. This last operation is assisted by heat. When this is done, pipe-clay carefully mixed up with water to the consistence of cream, is put upon the loaves to the thickness of about an inch; the water from this slowly percolates the loaves, and washing the solid sugar from all remains and tinge of the molasses, runs into the pots.

After this the loaves are dried by heat, and put up in papers for sale.

537. When sugar is heated it fuses, becomes brown, evolves a little water and is resolved into new arrangements of its component elements. If suddenly elevated to a temperature of about 500 degrees it bursts into flames.

538. Sugar is composed in round numbers of about 42 parts of carbon, 51 of oxygen, and 7 of hydrogen.

539. STARCH or *Fecula* may be separated from a variety of vegetable substances; it is contained in wheat and other esculent grains and in several roots.

Obs. The process for obtaining starch consists in diffusing the powdered grain, or the rasped root, in cold water, which becomes white and turbid. After some hours the grosser parts are separated by a strainer, and the liquor which passes deposites the starch, which is then washed in cold water and dried in a gentle heat.

540. Starch is insoluble in alcohol and in ether, and occasions no precipitate in the greater number of metallic solutions.

Obs. The most characteristic property of starch, is that of forming a blue compound with *iodine.*

541. During the germination of seeds the starch is converted into sugar.

542. Starch may also be converted into sugar by mixing it with sulphuric acid and water.

Exp. Digest a pound of starch in six or eight pints of pure water, rendered slightly acid by two or three drachms of sulphuric acid. The mixture should be simmered for two days, adding fresh portions of water to compensate for the loss by evaporation. The acid is then saturated by chalk, and the mixture filtered and evaporated to the consistence of syrup. This syrup has a sweet taste, and by purification in the usual way, it affords crystallized sugar. The quantity obtained exceeds the weight of the starch by about one tenth. Starch is composed of about 43 parts of carbon, 48 of oxygen, and 7 of hydrogen=100.

Obs. The principal varieties of starch are the following:—

Arrow root, *Potatoe starch*, *Sago*, *Tapioca*, *Cassava*, *Salop*, and the *starch of wheat*.

543. GLUTEN may be obtained from wheat flour, by forming it into a paste and washing it under a small stream of water. The starch is thus wasted away, and a tough elastic substance remains which is *gluten*.

Obs. Its colour is grey, and when dried, it becomes brown and brittle. It is nearly insoluble in water and in ether. When allowed to putrify it exhales an offensive odour, and when submitted to destructive distillation it furnishes ammonia, a circumstance in which it resembles animal substances.

India Rubber, and *bird lime* may also be considered as allied to gluten.

Wheat contains from 18 to 24 per cent. of gluten, the remainder being principally starch.

544. EXTRACTIVE MATTER. Most vegetables, when submitted for a time to the action of hot water, impart to it a brown colour. When this solution is evaporated, there remains a solid substance of a brown colour, which is *extractive matter*.

Obs. Extracts are prepared by the apothecaries as a means of concentrating the virtues of plants, for medical use. These extracts not only contain the proper extractive matter, but also several foreign substances.

545. There are many kinds of extractive matter, differing from each other in taste, quality, and virtue.

Obs. Extractive matter is soluble in water and in alcohol containing a small quantity of water. From these solutions it is precipitated by solution of chlorine, by many of the acids, and by most of the metallic oxides.

546. TANNIN is contained in abundance in nutgalls, in grape seeds, oak bark, catechu, &c. and in greater or less quantities, in all vegetables and roots which are *astringent* to the taste.

Obs. Tannin may be obtained from either of the above named substances, by first bruising the article, and then digesting it in a small quantity of cold water, and afterwards evaporating the water. It is of a yellowish brown colour, extremely astringent, and soluble in water and alcohol.

2. Tannin is distinguished by its affording an insoluble precipitate with isinglass, or any other animal jelly. It is on this principle that the art of tanning leather is founded. The hides are laid in vats, and between each two there is thrown a layer of oak, or some other bark, which contains tannin in coarse powder. The tannin of the bark combines with gelatine of the hide and renders it hard and impervious to water.

547. COLOURING MATTER. The colouring principles of vegetables are numerous, and various in their properties. The extraction of these principles, and the transfer of them to different substances constitutes the *art of dyeing*.

Obs. Colours have been divided into *substantive* and *adjective*. Substantive colours are such as do not require the intervention of any other substance to fix them permanently, their attraction for the cloth being sufficient. Adjective colours require the intervention of some substance which has an attraction both for the colouring matter and stuff to be dyed. This intervening substance is called a *mordant*. It consists of a metallic salt, with which the substance to be dyed is first impregnated and afterwards passed through a solution of the colouring matter.

The mordants most commonly employed are *sulphate of iron*, *muriate of tin*, *sulphate of alumine* and *acetate of iron*.

548. Different mordants are used for different colours, as well as for different kinds of cloth.

Illus. ***Black*** is produced by astringents and salts of iron. The stuff is first soaked in a strong solution of galls, and afterwards passed through a solution of sulphate of iron in an infusion of logwood.

2. ***Reds*** are chiefly produced from madder, and the colouring matter is fixed by a mordant of muriate of tin, &c.

549. FIXED OILS. Vegetable oils are of two kinds, *fixed* and *volatile*.

550. Fixed oil is found in the *seeds* of plants only, and is almost entirely confined to those which have two cotyledons, as linseed, almonds, walnuts, olives, &c.

551. These oils are obtained by pressure. They

are viscid, nearly insipid, and generally congeal at a higher temperature than that required to freeze water.

Obs. The fixed oils, with a few exceptions, undergo little other change by exposure to air, than that of becoming somewhat more viscid and acquiring a degree of rancidity. This change is owing to absorption of oxygen, for rancid oils redden vegetable blues, and therefore contains a quantity of free acid.

Some few of the fixed oils, on exposure to air, become covered with a thin pellicle, occasioned partly by the evaporation of their volatile particles and partly by the absorption of oxygen. These are called *drying* oils, and are used in painting. Of these oils, the most common is linseed oil, rape oil, and hempseed oil.

The alkalies combine with the fixed oils, and form soap.

The fixed oils are composed of carbon, hydrogen and oxygen.

552. VOLATILE OILS. These oils are obtained from plants by distillation. Some fruits however yield them by pressure; such as the lemon, orange, and bergamont, which contain the oil in distinct visicles in the rind of the fruit.

553. The volatile oils have a penetrating odour and taste, and contain the odoriferous principle which distinguishes the aromatic plants. It is indeed the volatile oil, to which the smell of plants is owing.

Obs. 1. These oils are soluble in alcohol, and very sparingly so in water. When dissolved in the former they constitute *essences*, a great variety of which are manufactured, particularly at Paris, and are used as perfumes. Waters, holding a small portion of aromatic oil, in solution, are called *distilled waters.* A variety of these are used in medicine.

2. The volatile oils when pure, pass off by evaporation, without leaving any stain on white paper. Hence a good test of the purity of these oils, is to let a drop fall on paper, and if an oily spot is left after the paper is warmed, it has been adulterated by some fixed oil.

FERMENTATION.

Def. Fermentation is a spontaneous commotion in a vegetable substance, by which its properties are totally changed.

554. There are several circumstances required, in order that fermentation may proceed, viz. a certain degree of fluidity, a certain degree of heat which is between 55 and 65, of Faht., and a saccharine mucilage, which must be in considerable quantity. When these conditions are united, the spirituous or vinous fermentation takes place, and is attended by the following phenomena. A brisk intestine motion, with the escape of carbonic acid gas; the transparency of the fluid being diminished by the rising of opake filaments, at the same time a considerable degree of heat is generated. All these phenomena, gradually cease in proportion as the liquor loses its sweet and mild taste, and as it becomes brisk, penetrating, and capable of producing intoxication.

Obs. After a vegetable solution has undergone the *vinous* fermentation, as above described, and by which beer, wine, cider, &c. are formed, it proceeds on to the *acetous* fermentation. During this latter process, there is no commotion nor extrication of any kind of gas, but on the contrary, *oxygen* is absorbed from the atmosphere, so that for the making of vinegar, the air is absolutely necessary.

555. The principal substance concerned in the vinous fermentation is sugar; and no vegetable juice can be made to undergo the process, which does not contain it in a very sensible quantity. In the production of beer, the sugar is derived from the malt, the *farinaceous* being converted into *saccharine* matter, by the process of malting. In the production of wine the sugar is derived from the juice of the grape.

556. After a vegetable solution has passed through the vinous fermentation it is found to have lost a part of its specific gravity, and to have acquired a new flavour. and a new power, viz. that of producing intoxication. These new properties

depend on the *alcohol* formed by the fermentative process.

Obs. Any fermented liquor by distillation affords a *spirituous liquor*. *Brandy* is obtained by the distillation of wine. *Rum* is obtained from the fermented juice of the sugar cane. *Gin* from fermented rye, &c.

557. When any of those spirituous liquors are re-distilled, *alcohol* or *spirits of wine* is obtained.

Obs. It has been a subject of controversy whether the alcohol which is obtained by the distillation of fermented liquors, existed ready formed in those liquors, or whether it was actually *produced* during the process of distillation. This question Mr. Brande has settled beyond further dispute, by showing that alcohol can be separated from fermented liquors, without the aid of heat or distillation.

ALCOHOL.

558. When a fermented liquor is distilled, there is obtained a quantity of alcohol, but always mixed with water, and impregnated with a small portion of essential oil, which gives it a flavour peculiar to the vegetable which formed the fermentative solution. Thus *brandy*, *rum*, and *gin*, each have a taste and smell peculiar to themselves. These are called *spirituous liquors*.

559. When a spirituous liquor is distilled, the alcohol is obtained in a state of much greater purity, the oil which gives the flavour and most of the water being left in the retort.

560. Alcohol is a colourless liquid, considerably lighter than water, being in the proportion of 800 to 1000.—It has considerable odour, and a penetrating taste; is highly inflammable; remarkably expansible by heat, and unites chemically with water.

Obs. The flame of alcohol acquires a red colour on mixing it with a little muriate of lime; a deep blood red from muriate of strontites, and a green from boracic acid.

561. Alcohol has never been frozen, although exposed to the lowest temperatures which has been produced by art.

562. It is a powerful solvent. It dissolves camphor, resins. soap, volatile oils, sugar, balsams, several of the solid acids, &c.

563. Alcohol, according to the analysis of Saussure, is composed of carbon 51.98; oxygen 34.32, and hydrogen 13.70 = 100.

Obs. Alcohol, when pure, is exactly the same, from whatever kind of spirit it is distilled. The intoxicating effects of all kinds of distilled liquors depend on the alcohol they contain.

ETHER.

564. Ether is an extremely light, fragrant and volatile fluid, produced by the distillation of alcohol with an acid.

Obs. There are several kinds of ether, all agreeing in the above general qualities, but differing in respect to flavour, specific gravity, and some other properties. This difference depends on the acid with which the alcohol is distilled.

565. *Sulphuric ether* is prepared by the distillation of sulphuric acid and alcohol.

Exp. Pour into a tubulated retort, a certain quantity of alcohol, by weight, and add to it in small portions at a time, the same weight of concentrated sulphuric acid, allowing time for the mixture to cool after each addition. Let the retort be placed in a sand bath, previously heated to 200 degrees, and connect it with a tubulated receiver, by means of an adopter. The receiver must be kept cold by means of moistened cloths.

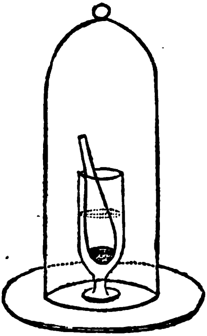
As soon as the mixture begins to boil, ether is produced, and passes over into the receiver. The ebullition is to be continued until white vapours appear in the receiver, or a sulphurous smell is perceived, and then the receiver is to be removed. The ether will be found to have a sulphurous smell.

To purify it, mix with it a small quantity of black oxide of manganese, and a quantity of water, and distil again. Sulphuric ether, in a tolerable state of purity, will be thus obtained.

566. Sulphuric ether is extremely volatile, and by its evaporation produces cold.

Illus. 1. A few drops poured on the hand produces a sensation like a piece of ice. If a small stream of it be poured from a capillary tube, on the bulb of a thermometer filled with water, the water will be frozen even in summer.

2. Ether evaporates with such rapidity that the singular phenomenon of boiling and freezing may at the same time be shown by means of it.



For this purpose, procure a very thin flask, which fits loosely into a wine glass, as shown in the figure. Pour a small quantity of ether into the flask, and put some water into the glass, and place the whole under the receiver of an air pump. During the exhaustion, the ether will boil, and a crust of ice will form on the flask.

Obs. 1. Ether does not, like alcohol, combine with water, but if the two fluids be shaken together, the ether soon separates and rises to the top.

2. By repeated agitation with water, ether is brought to a great degree of purity, and acquires the property of dissolving India rubber.

3. It dissolves essential oils and resins. It also dissolves a small portion of phosphorus, which, when poured on warm water, emits a lambent blue flame.

4. When kept for a long time in a bottle only partly filled, and frequently opened, sulphuric ether undergoes a spontaneous change. It becomes acid in consequence of the production of vinegar, and loses somewhat of its sweet odour and volatility.

Sulphuric ether is composed of carbon 67.98 ; oxygen 17.62 ; hydrogen 14.40=100.

567. *Nitric ether* is prepared by the distillation of alcohol and nitric acid.

Illus. To two pints of alcohol contained in a retort, add by degrees, half a pound of nitric acid, cooling the retort after each addition. Then distil by a heat cautiously regulated, about a pint and a half. It must be purified by adding to it some potash and re-distilling.

Caution. Great care must be taken not to add too much of the acid at a time, nor to apply the heat too fast; in either case a dangerous explosion would ensue.

568. Nitric ether is of a yellowish colour. It has an excessively pungent odour, so that its in-

halation into the nostrils produces giddiness. Its taste is acid and burning. Like sulphuric ether its evaporation produces cold. It is extremely inflammable, and burns with a white flame. It is composed of carbon, hydrogen, nitrogen, and oxygen.

Obs. The others are the *muriatic ether*, the *chloric ether*, *acetic ether*, *benzoic ether*, *&c.*

ELECTRO-CHEMISTRY.

569. If a piece of sealing wax or glass be rubbed with the dry hand, or with dry flannel, the wax or glass and the cloth, become capable of attracting and repelling small light bodies. In these cases the substances are said to be in a state of *electrical excitement.*

Illus. Make two balls of pith, or cork, about the size of peas, and suspend them with silken threads. If now a stick of sealing wax, or glass be rubbed with fur or flannel, and the sealing wax be made to touch the cork balls, they will *repel* each other, but if one of the balls be touched with the wax, and the other with the fur, or flannel, they *attract* each other.

Obs. This experiment shows that when bodies are electrified alike, or are in the same state of electrical excitement, they repel each other, but that when they are in opposite electrical states, they attract each other.

570. Some bodies permit electricity to pass through their substance, and for this reason they are called *conductors.* Others only receive it upon the spot touched, and are called *non-conductors.*

Obs. 1. The conductors of electricity are called *non-electrics*, because they cannot be excited by friction; or, in other words no difference can be observed in their electrical states on rubbing them.

The non-conductors, on the contrary are *electrics*, or acquire the power of attraction and repulsion by being rubbed.

2. All the metals, with the exception of selenium, are *perfect* conductors. Water, steam, damp wood, damp air, alcohol, melted wax, charcoal, and many other substances are *imperfect* conductors.

3. Dry air, sealing wax, solid bees wax, glass, rosin, fur, silk, wool, and some other substances are non-conductors.

4. Any of the non-conductors admit of electrical excitement by friction.

571. When one part of a body, or system of bodies is in the positive state, the other part or system is invariably in the negative state.

Illus. If one end of a stick of sealing wax, or one side of a plate of glass be rubbed with a piece of silk or fur, and the two sides or ends be successively presented to two separate, excited balls, one of the balls will be repelled, and the other attracted; and if the silk or fur be presented to the ball it will always indicate a contrary state to the substance with which it was rubbed.

Obs. The *positive* and *negative* electrical states, consist merely in the accumulation, or absence of the electric fluid. Thus if a body, or any part of a body has more than an ordinary share of electricity, it is said to be in the positive state: if it has less, it is in the negative state.

572. When any conductor is wholly surrounded by non-conductors, it is said to be *insulated.*

Illus. The human body is a conductor; but if a person stand on a cake of wax, or a board set on glass bottles, and in that state is electrified, another person standing on the ground will receive a shock on touching him.

573. When an insulated conducting body contains more or less of the electric fluid than its ordinary share, or when one side of an electric contains more of the fluid than the other, in this state such bodies are said to be *charged.*

Obs. When the electricity passes from a negative to a positive surface, if this passage is made through an animal, it produces an affection of the nerves called an *electric shock.*

GALVANIC ELECTRICITY.

574. There are other sources of electricity besides those mentioned above. Animal substances, charcoal, the metals, and some other substances, when arranged in a certain order are capable of exhibiting electrical phenomena.

In the year 1791, Galvani, an Italian professor, first observed some phenomena which laid the foundation for the science of galvanism. Being engaged in a course of experiments on animal irritability, he accidentally observed that contractions were excited in the limbs of a frog by applying a conductor between a nerve and a muscle.

The theory he frames to account for this phenomenon, was, that the different parts of an animal are in opposite states of electricity, and that the effect of the metal is merely to restore the equilibrium. This theory, however, was afterwards shown by Volta, to be without foundation, who excited similar contractions by making a connection between two parts of a nerve, between two muscles, or between two parts of the same muscle, but in all these cases the contact of two different metals were always found to be essential.

From the time of Galvani's discovery, philosophers continued to make experiments on this subject, and to discuss the cause of these phenomena, until early in the year 1800, Signior Volta, discovered what has since been called the *galvanic pile*. From this period discoveries have multiplied on this subject, in a manner unparalleled in the history of any other science.

575. The conditions necessary to excite the galvanic influence are altogether different from those which excite common electricity.

Illus. Electricity is excited whenever two dry electrics, or non-conducting surfaces are rubbed together. In the galvanic excitation, such substances as are called electrics have no share in the phenomena. All that is required is the contact of *different* conducting bodies with each other. These conducting bodies must be placed in a certain relation to each other, so that they will form a *circle* or series of conductors.

576. A *simple galvanic series* consists of three conductors, two of which must be of one class, and one of another class.

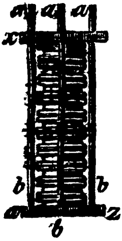
Exp. Take a piece of silver, as a dollar, and place it upon the tongue; take also a piece of zinc and place this under the tongue, both pieces must touch the tongue, but not each other. In this state no sensation is excited, but on bringing them in contact, there will be excited a peculiar saltish, or metallic taste; and if the eyes are shut there will be perceived a small flash of light.

Obs. In this experiment we have an example of galvanic arrangement, and of a slight galvanic action. The two metals are *two* perfect conductors, and the tongue or rather the moisture on it *one* imperfect conductor. The metallic taste is owing to galvanic action.

577. It is by an extension of this principle, and by multiplying the series that powerful galvanic effects are produced.

Illus. The GALVANIC PILE, or pile of Volta is made on this principle.

Take a convenient number, say twelve plates of copper, and the same number of pieces of zinc; they may be two inches in diameter and the tenth of an inch thick; take also the same number of pieces of woolen cloth of the same diameter; pile these up in a frame made of three glass rods supported by two end pieces of wood, in the following order. First a piece of copper, then one of zinc, and then a piece of cloth wetted in a solution of muriate of ammonia in water, then a plate of copper, and so on ending with the zinc. The fig. represents such a pile, *a b*, are the glass rods, and *x z* the pieces of wood.



Such a series affords a constant stream of the galvanic fluid, but is most powerful immediately after it is completed, or before the plates have become oxidated. A pile composed of two dozen plates of two inches diameter, when first constructed will give a small shock, which is not commonly felt higher than the elbows when taken by the hands. The mode of receiving the shock is to wet the hands and placing one of them on the plate of copper, or zinc at one end of the pile, touch that at the opposite end with the other hand, or to touch the two end plates with wires held in each hand, the hands being wet.

578. The galvanic influence is extricated only on condition, that one of the metals employed in constructing the series be more easily oxidated than the other.

Obs. The galvanic pile may be made of any two metals, one of which, has a stronger affinity for oxygen than the other, and the positive side is always that on which the most oxidable metal is placed. Thus in the directions above given for constructing the pile, the upper end would be the positive because it terminates with a zinc plate, zinc being more oxidable than copper.

579. Any metal, except that which is the least

oxidable of all, may be made the positive, or negative side by being placed in contact with one, more or less oxidable than itself.

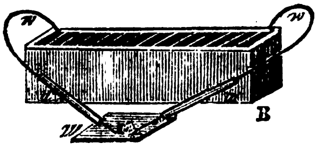
Illus. Copper when placed with zinc is always negative, but when in contact with silver, or gold, it is positive.

Obs. The greatest effect is produced by placing together the most oxidable metal, with that which is least so, as zinc and platina.

580. In the construction of a galvanic series, the plates must be so arranged that an accumulation of power is constantly effected through the whole. Thus the power of the first pair of plates as it passes through the series is doubled at the second, trebled at the third, and so increasing in proportion to the number of double plates.

Illus. In the voltaic pile, the fluid is conducted from one pair of plates to the other by the water contained in the woollen cloths.

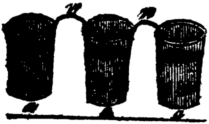
581. This principle may be so modified as to dispense with the cloths, while the water is retained, and and as such an arrangement possesses several advantages over the pile it is now generally adopted.



Illus. For this purpose square plates of copper and zinc, previously soldered together, are placed in grooves cut opposite to each other in a long, narrow wooden trough. These are cemented in their places, so as to make each cell water tight. This is called a *galvanic trough;* see fig. where A. B. is the trough made of baked wood, four inches broad and as many deep; *w w* are wire conductors fastened to the end plates, or merely dipped into the cells; *a a* are glass tubes, through which the wires pass, so as to handle them without receiving the shock; *v* is a plate of glass on which the subject of experiment is laid. One of these troughs containing 24 or 30 four inch double plates, will show many amusing and some striking experiments. When it is to be used, the cells formed by the plates are filled with water containing in solution a few ounces of common salt or sal ammoniac, or made slightly sour by nitric or muriatic acid. If the water is made warm, the action will be much increased. After the trough is filled with water, it is proper to wipe its edge, and those of the plates dry, and also to observe that it does not leak, otherwise the galvanic fluid will be conducted off. The shock may be taken, by dipping a finger of each hand into the water at the ends of the trough. When it is required to pass the fluid through a particular part, place a piece of wet rag on the two opposite points, and touch them with the wire conductors.

582. Another mode of constructing the galvanic apparatus, is by arranging a row of glasses containing solution of common salt in water, or dilute sulphuric, muriatic, or nitric acid, and the two metals.

Illus. In each of these glasses are placed a plate of silver or copper, and one of zinc, not touching each other, but so connected by metallic wires, that the zinc of the first cup may communicate with the copper of the second; the zinc of the second with the copper of the third; and so throughout the series, except of the two outside cups, which contain only a plate each, one of copper, and the other of zinc, as represented in fig. 36, where *a a a* are the glasses, *z* zinc, *x* copper, and *w w* the wires which connect the copper and zinc plates. The shock is felt by dipping a finger of each hand into the two outside glasses. The superiority of this mode of arrangement over that of the common trough, consists in the exposure of both surfaces of the plates to the action of the liquid; whereas, by soldering the plates together, one of the surfaces of each is protected from the liquid, and contributes nothing to the effect. Some improvements have, however, been lately made in the construction of the trough, which is said greatly to increase its power. Two plates of copper are placed in each cell on each side of the plate of zinc, so that both surfaces of the zinc plates are acted on by the liquid. This is said to increase the power of a battery one half.



583. Whenever it is required to increase the power of a galvanic battery above that of a common trough, this is done by connecting many troughs together by a wire passing from the zinc

end of one, to the copper end of the other. The two ends of this chain of troughs are then connected, and the circuit completed at pleasure by two wires fastened to the first and last troughs. In this manner batteries of immense power have been constructed.

Illus. The celebrated one, belonging to the Royal Institution of Great-Britain, is the most powerful that has yet existed. Its effects are indeed surprising. It consists of two hundred porcelain troughs, each containing ten cells, and ten double plates; so that the whole number of double plates is two thousand; and each plate contains thirty two square inches, the whole surface amounts to 128,000 square inches. This battery, when the cells were filled with 60 parts of water mixed with one part of nitric acid, and one part of sulphuric acid, afforded a series of brilliant and impressive effects. When pieces of charcoal about an inch long, and one sixth of an inch in diameter, were brought within the circuit and near each other, a bright spark was produced, and more than half the volume of the charcoal became ignited to whiteness, and by withdrawing the points from each other, a constant discharge took place *through* the heated air, in a space equal at least to four inches, producing a most brilliant ascending arch of light, broad, and conical in form, in the middle. When any substance was introduced into this arch, it instantly became ignited; platina melted as readily as wax in the flame of a common candle; quartz, the sapphire, magnesia, and lime, all entered into fusion; fragments of diamond, and points of charcoal of plumbago, rapidly disappeared and seemed to evaporate in it.—(*Davy*.)

QUESTIONS

FOR EXAMINATION.

N. B. The most important questions, and those which the pupil ought readily to answer, are printed in Roman letters ; the others are in Italics.

What is CHEMISTRY ?

What is the object of CHEMICAL PHILOSOPHY ?

What is the FOUNDATION of chemical philosophy ?

What are the ENDS, or OBJECTS, of this science ?

What useful INVENTIONS or IMPROVEMENTS has this science been the means of effecting ?

How is CHEMICAL KNOWLEDGE chiefly obtained ?

What are crucibles, and what their uses ?

What is the figure of a mattrass, and what is its use ?

What is the form of a retort, *and what its use ?*

What is a receiver, *and what its use ?*

What is an alembic, *and what are its uses ?*

How may Florence flasks *be fitted so as to answer the purposes of retorts ?*

Describe the construction and principle of the air thermometer.

Describe Fahrenheit's thermometer.

Describe the common blow-pipe *and method of using it.*

Describe the compound blow-pipe.

What are the gases burned by this blow-pipe ?

How do you account for the intense heat which it gives ?

What is the principle on which the SPECIFIC GRAVITY of liquids are told, by means of a gradulated bottle ?

Describe the cryophorus *or frost-bearer.*

What is a bell glass receiver ?

What is a dropping tube ?

Describe the method of retaining such gases as are absorbed by water, and lighter than air, without a mercurial bath.

Describe the GAS APPARATUS and the method of pouring air from one vesssel to another.

Describe the DIFFERENTIAL THERMOMETER.

Describe the LAMP FURNACE.

Describe the APHLOGISTIC LAMP.

How is the ignition of the platina wire kept up?

Why will not other metals answer for this purpose instead of platina?

ON THE FORMS OF MATTER.

Under how many GENERAL FORMS does MATTER exist, and what are those forms?

What are SOLIDS? and what causes solidity?

What are FLUIDS? and what causes fluidity?

How can SOLIDS be converted to *fluids*, and fluids to the ELASTIC state?

When does mercury *become a* solid *malleable metal?*

What are elastic *fluids?*

On what does their PERMANENT ELASTICITY depend?

What follows from the above considerations?

What would be the probable effect of removing the earth out of the sun's heat? and what the effect of its near approach to the sun?

ON SIMPLE SUBSTANCES.

What is meant by a SIMPLE SUBSTANCE?

What is their number?

What are the IMPONDERABLE bodies?

How are the PONDERABLE bodies classed?

How are these classes divided?

Which among the EARTHS are known to have metallic bases?

Why are the known metallic earths, and those of doubtful characters arranged together?

HEAT.

What is HEAT? How does heat differ from CALORIC?

How is it proved that heat seeks an equilibrium?

What are the two states *in which heat may exist?*

How is it known on touching a body whether it contains caloric in a free state?

How does COMBINED caloric differ from FREE CALORIC.

FREE CALORIC.

Under what views may CALORIC, as a CHEMICAL AGENT, be considered?

What effect does it have as the ANTAGONIST to COHESION?

What happens among the particles of a fused substance, as the caloric passes out?

How does caloric cause, or increase *the elasticity of bodies?*

On what circumstance does the PERMANENT ELASTICITY of fluids depend?

Why may the receiver of an air pump be considered as full of air after the utmost exhaustion?

EXPANSIVE POWER OF CALORIC.

It is said that bodies are expanded *by heat, and* contracted *by cold: what* class *of bodies expand most by the same increase of heat?*

Do the metals *expand alike at the same temperatures?*

How is this shown?

What experiment will shew that liquids *do not expand alike at the same rise of temperature?*

Do the ELASTIC FLUIDS expand at the same ratio, at equal increments of heat?

What is the rate *at which elastic fluids expand?*

How may the expansion of air be shown?

RADIATION OF CALORIC.

What is RADIANT caloric?

What are the phenomena *of radiant caloric?*

At what rate does it pass through space?

It is said that radiant caloric can be reflected. Describe the experiment by which this is done.

By what routine does the heat of the ball reach the thermometer in the focus of the other mirror?

Do the same surfaces *reflect* caloric *and* light *equally well?*

How is it shown that metals reflect heat better than glass?

What effect does the colour *of a* surface *have on the reflection of heat?*

How is it shown that some surfaces reflect caloric better than others?

What must the nature of the surface be to reflect most or least rapidly?

CONDUCTORS OF CALORIC.

In what DIRECTIONS do SOLID BODIES conduct caloric?

How is this shown?

How does caloric diffuse itself through liquids and elastic fluids?

How is it shown that fluids do not CONDUCT, but CONVEY caloric

COMBINED CALORIC.

What happens in respect to caloric, when a SOLID is converted into a FLUID ?

What happens when a FLUID is converted into a SOLID ?

What is said concerning the absorption of caloric, during the melting of ice ?

What becomes of the caloric which is absorbed by the ice ?

How is it shown that melting ice absorbs a quantity of caloric, which is not indicated by the thermometer ?

To what is the FLUIDITY of WATER owing ?

How is it shown that CALORIC is ABSORBED during the conversion of LIQUIDS into VAPOUR ?

From whence does the ether obtain caloric in the experiment with the thermometer ?

What is said of the latent caloric in steam ?

How many degrees of latent heat is it calculated steam contains ?

When do liquids, or elastic fluids evolve caloric ?

How is it shown that WATER gives out HEAT when it freezes ?

How is it shown that the COMPRESSION of AIR produces heat ?

SPECIFIC HEAT.

What is understood by SPECIFIC HEAT ?

Do different substances of the same temperature contain *the same quantities of heat ?*

What are the EXPERIMENTS elucidating the doctrine of latent heat ?

What unexpected facts do these experiments prove ?

Which has the greatest CAPACITY for heat, MERCURY or WATER ?

SOURCES OF CALORIC.

What are the SOURCES of caloric ?

In what way is it shown that PERCUSSION produces heat ?

From whence comes *the heat evolved by percussion ?*

On what principle is it, that heat is produced by friction ?

How does MIXTURE produce heat ?

What is the reason that sulphuric acid and water when mixed, occupy less space than before ?

What is the 6th source of heat ?

How far, and in what respect, are the phenomena of light connected with chemistry ?

How is light decomposed ?

Are the HEATING POWERS of the different PRISMATIC RAYS alike ?

Where with regard to the spectrum is the greatest heating power?

What is said concerning the ABSORPTION of LIGHT?

What are bodies called which absorb, and again give out light?

How is Canton's phosphorus prepared?

What curious property has this substance?

What is said of the power of the diamond *in this respect?*

How is the extrication of light facilitated from the solar phosphori?

Is LIGHT ever extricated without HEAT?

Mention some substances which give out light without heat.

What is said of LIGHT as a CHEMICAL PRINCIPLE in bodies?

What experiments show this fact?

What is said of the EFFECTS of LIGHT on PLANTS?

Under what circumstances do PLANTS emit OXYGEN?

What is said of the influence of light on the crystallization of salts?

ON AFFINITY.

What is ATTRACTION?

What is the cause of attraction?

How will you prove the existence of ATTRACTION?

How does the spherical form of the drops of a fluid prove the existence of attraction?

What is attraction of GRAVITATION?

What is COHESIVE AFFINITY?

Does this kind of affinity operate on the particles, *or* masses *of matter?*

What is CHEMICAL AFFINITY?

What is the difference between cohesive attraction *and* chemical affinity?

How is this difference illustrated?

How is chemical affinity divided?

What is ELECTIVE AFFINITY?

What is COMPLEX AFFINITY?

What is the difference between these two kinds of affinity?

In what class of bodies is cohesive affinity *most strongly exerted?*

How may the cohesion of bodies be overcome?

Why are substances more easily soluble in the state of powder than in the mass?

To what is heat the antagonist force?

How does HEAT overcome the POWER of COHESION?

On what does the cohesive attraction depend?

In what manner does the HEAT destroy the COHESION of particles?

What is SOLUTION? or how is this term applied?

How does a fluid overcome the cohesive force of the particles of a solid?

What is CRYSTALLIZATION?

What connection has been observed between the chemical COMPOSITION, and external FORMS of crystals?

How are the INVARIABLE FORMS of CRYSTALS accounted for?

Do substances of different chemical compositions ever crystallize under the same forms?

What is the DISTANCE at which CHEMICAL AFFINITY is effective?

Does chemical affinity bring particles of DIFFERENT kinds to unite, or those of the SAME kind?

What effect does chemical union have on the corrosive qualities of the acids and akalies?

When is an acid said to be SATURATED?

Does saturation destroy *the active principles of an acid, or only* restrain *its action?*

What is the GENERAL EFFECT which chemical combination has on the PROPERTIES of bodies?.

Give some illustration of this effect.

What is the difference between mixture *and* combination?

What are four of the most OBVIOUS CHANGES which result from chemical combinations?

Give an example of the change of colour.

Give an example of the change of specific gravity.

In what cases does change of temperature *take place?*

Give some examples of the changes of form.

Give an illustration of ELECTIVE AFFINITY?

What will be the chemical effect *of adding* sulphuric acid *to a solution of* muriate of lime?

Draw a diagram to illustrate elective affinity.

Construct a short table showing the relative forces of affinity be-between several substances.

What are the uses of tables, showing the relative force of affinity?

From what circumstance is it inferred that the force of chemical affinity *is great?*

Under what circumstances does COMPLEX AFFINITY take place?

Describe the changes of composition which take place, when muriate of lime *and* sulphate of soda, *are mixed together.*

What is the cause of the turbidness *which attends this* mixture?

ON THE GASES.

What is a GAS ?

From whence are the gases obtained ? and by what means ?

In what respect are the gases unlike *each other ?*

In what respect do they agree ?

Of what do the gases CONSIST ?

On what do the WEIGHT of the gases depend ?

On what does their ELASTICITY depend ?

At what rate do the gases EXPAND by heat ?

What relation is there between the BULK of a gas and the PRESSURE which it sustains ?

To what extent can the BULK of a gas be REDUCED by pressure, or INCREASED by its removal ?

By what substances are the gases absorbed ?

What number of gases are enumerated?

How are they classed and divided ?

OXYGEN GAS.

Why has not the base, or ponderable part of oxygen gas been examined in a separate state ?

What is the TASTE and SMELL of OXYGEN GAS ?

What is the common method of procuring this gas ?

From what substances besides MANGANESE can it be obtained ?

How is it procured from the leaves of plants ?

What are the PECULIAR PROPERTIES of this gas ?

What phenomena are produced when zinc or iron is heated in this gas ?

What effect does it have on burning bodies in general ?

What effect is produced on the WEIGHT of a METAL when burned in this gas ?

From whence does it GAIN this ACCESSION of weight ?

What new NAME do the METALS acquire after COMBUSTION in this gas ?

What effect does oxygen have on the colour of blood ?

What new compound *is formed when* sulphur *is burned in the gas ?*

NITROGEN.

What does NITROGEN signify ?

What effect does this gas have on BURNING BODIES ?

What are its effects on ANIMALS ?

What IMPORTANT COMPOUND does it form when mixed with OXYGEN gas ?

How can nitrogen be obtained ?

COMMON AIR.

What is meant by AIR?

How is it easily recognized?

Of what is AIR COMPOSED?

What are the proportions of OXYGEN and NITROGEN in the air?

How do these two gases differ when separated?

How can they be separated?

What is the INSTRUMENT called by which the PURITY of the atmosphere is determined?

Describe one of the most simple EUDIOMETERS and the method of using it.

What DIFFERENCE has been detected in regard to the PURITY of the air, at different places?

In what does the SYNTHESIS of the AIR consist?

What effect does the RESPIRATION of ANIMALS produce on common air?

What is the reason that an ANIMAL cannot LIVE where a COMBUSTIBLE will not BURN?

What PRECAUTION should be taken before *descending* into a place where FOUL AIR might be suspected?

HYDROGEN GAS.

From whence is the word HYDROGEN derived?

In what state has hydrogen been examined?

What does the BASE of this gas form when united to OXYGEN?

What becomes of the HEAT and LIGHT, when these two gases are CONDENSED into the form of WATER?

Describe the method of procuring this gas.

Explain the PRINCIPLE on which it is formed by this experiment.

How is this gas formed when water is passed through a gun-barrel.

What is the comparative WEIGHT of this gas and common air?

How may its levity be shown?

What CAUTION is advised before setting fire to bubbles of HYDROGEN and OXYGEN?

How are MUSICAL TONES produced by the burning of this ga

What is PRODUCED in all cases when hydrogen is BURNED?

How is this fact shown?

WATER.

What is the composition of WATER?

How does oxygen *and* hydrogen *form water?*

Describe a simple method *of forming* water *by the burning of hydrogen.*

In what manner is water decomposed when we obtain only one of its constituents?

By what process can we separate and retain both of the elementary principles of water?

In what proportions *do oxygen and hydrogen exist in water?*

Is wood *capable of decomposing water?*

What gas is emitted when water is decomposed by wood?

How does wood effect this decomposition?

CHLORINE.

What is the colour *of* chlorine?

Why has it received this name?

What is its SPECIFIC GRAVITY?

What would be the consequence *of* breathing *it?*

How is this gas obtained?

What effect does it have on VEGETABLE COLOURS?

What effect does this gas have on the metals?

By what agency does a mixture of chlorine *and* hydrogen explode?

What precautions *are to be used in making this experiment?*

ON THE SIMPLE SOLIDS.

IODINE.

From what is the name *of this substance derived?*

What is the form *and* appearance *of iodine?*

What is its taste *and what are its* qualities?

From what substance *is iodine* obtained?

What is the PROCESS of obtaining it?

What are the peculiar properties *of this substance?*

PHOSPHORUS.

What is phosphorus?

From what substance *is it obtained?*

What caution *is necessary in handling it!*

How may it be set on fire?

How is liquid *phosphorus made?*

What is the consequence of rubbing phosphorus with oxymuriate of potash?

What is the process for making phosphuretted hydrogen?

How is phosphuret of lime *made?*

What are the peculiar properties of this substance?

In the formation of phosphuretted hydrogen, *by means of* phosphorus, *from whence comes the* hydrogen?

Where is phosphorus chiefly found?

SULPHUR.

Where is sulphur *chiefly found?*

From whence comes the sulphur of commerce?

How may sulphur be made soft *and* tenacious *like wax?*

What is the difference between sulphur *and* brimstone?

What are the substances with which sulphur combines, and what are these compounds called?

In how many proportions *does sulphur combine with* oxygen, *and what are the* products *called?*

CARBON.

What is CARBON?

In what FORM does PURE CARBON exist?

How is carbon procured?

What effect *does* heat *have on charcoal when it is* covered *from the air?*

What effect does newly made *charcoal have on* fetid odorus?

What is said of its use as a tooth powder?

What effect does it have on putrid water?

What are the effects of air *and* moisture *on charcoal at* common temperatures?

Does carbon unite with other substances?

What are these compounds called?

What is the chemical name of black lead?

What is the difference *between* iron *and* steel?

When carbon *is* burned *in* oxygen gas, *what is the* product?

By what other means may CARBONIC ACID gas be procured?

How much heavier is this gas than common air?

What EFFECT does it have on FLAME and LIFE?

What precaution *ought to be taken before* descending *into* old wells?

With what substances *does* carbonic acid combine?

What are the compounds of carbonic acid and a base called?

Among these compounds, which are the most important?

What is formed when caustic lime combines *with this acid?*

How will you prove *that* lime *absorbs* carbonic acid?

How is it proved that this gas is formed during the RESPIRATION OF ANIMALS?

How is it proved that PLANTS absorb this gas?

What is said of its existence in FERMENTED LIQUORS?

ON THE METALS.

By what PECULIAR properties are the METALS distinguished?

Are the metals all of them fusible?

What are those metals called which can be extended *under the* hammer?

What are those called which extend *under the* rolling press?

What are the metals called when they are COMBINED with each other by FUSION?

What can you say about the specific gravity *of the metals?*

Do the metals transmit light?

What is meant by the word ANNEALING?

What kind of a change *do the* metals *(except gold, silver, and platina,) undergo when exposed to the* air *and* moisture?

Why is the WEIGHT of a metal INCREASED by being changed into an OXIDE?

How can it be said, that all the METALS are COMBUSTIBLE bodies.

In what STATE are the METALS SOLUBLE in acids?

Why does not gold *dissolve in nitric acid*?

How is it proved that their UNION with OXYGEN increases the WEIGHT of the METALS?

How can the OXIDES of the METALS be REVIVED, or brought back to their metallic states?

When a metal is reduced *by charcoal, what* gas *is there* formed *by the* process?

What alteration does mercury undergo, when submitted for a long time to moderate heat?

What compounds *are formed by a union of* sulphur *with the metals?*

When phosphorus *unites to a metal, what is the compound called?*

Of what are the carburets *composed!*

How is the rapid production *of heat accounted for, when* iron filings *and* sulphur *are mixed, and gently warmed?*

What is a METALLIC SALT?

How are the red FUMES produced when a METAL is dissolved in NITRIC ACID?

For what purposes are the metallic salts used?

What metallic salts are particularly useful in dyeing?

What are the EFFECTS of the PURE METALS on the STOMACH?

How can glass be tinged so as to resemble the precious stones?

Do the metals when melted with each other enter into chemical union?

What effect does the ALLOYING of the METALS have on their SPECIFIC GRAVITIES?

Of what is the alloy composed which melts in boiling water?

Why do alloys oxidize more readily than pure metals?

How are the metals extracted from their ores?

What are the names of the malleable *metals?*

What are the names of the brittle *metals?*

What metals are fused *with* difficulty?

What are the names of the infusible *metals*?

GOLD.

What is the specific gravity of GOLD?

What is said of the malleability *of this metal?*

What effect does intense and long continued heat produce on this metal?

What are the acids *which* dissolve *gold?*

Describe the method of gilding steel *with the etherial solution of gold?*

PLATINA.

What is the specific gravity of PLATINA?

From what country is this metal brought?

In what respect is platina *like* iron?

How may platina be melted?

How may this metal be oxidated?

What is the solvent *of* platina?

What is said of the alloys *of this metal?*

What is said of the ductilty *of this metal?*

What is said of its power to conduct heat?

SILVER.

What is said of the SPECIFIC GRAVITY, MALLEABILITY, and DUCTILITY of SILVER?

Does heat oxidate *silver?*

What is the solvent *of this metal?*

What is the process of making LUNAR CAUSTIC?

How is indlible ink *made?*

What substances precipitate silver from its solution?

How can you cover a slip of copper with silver?

Describe the process of making Diana's silver tree?

How is silvering powder *prepared?*

What is the process of silvering ivory?

How can silver *be dissolved without touchiug* gold, copper, lead, *or* iron?

MERCURY.

What is the SPECIFIC GRAVITY of MERCURY?

At what degree below zero does it assume the solid form?

How may mercury be oxidated?

What are the metallic mixtures with mercury called?

How do the gold beaters obtain small particles of gold, by means of mercury?

How is Vermillion *prepared?*

Describe the method of silvering looking-glasses.

What *are the principal uses of this metal?*

What is said of Rhodium, *Palladium, Iridium, and Osmium?*

COPPER.

What is the specific gravity of COPPER?

What is said of the ductility, malleability *and* tenacity *of this metal?*

What is said of the combination of copper with the acids?

How can iron be covered with a coat of metallic copper?

What is the experiment with nitrate of copper *and* tinfoil?

What is the rationale *of this experiment?*

What is verditer? *How is* verdigris *prepared?*

How is copper obtained from streams of water containing a solution of its sulphate?

How is BRASS formed?

What other alloys of copper are valuable in the arts?

What is said of copper vessels *for* culinary *purposes?*

What is one of the best TESTS for the presence of this metal?

IRON.

What is said of the *abundance* and *usefulness* of IRON?

What is the SPECIFIC GRAVITY of iron?

What is said of its malleability, *and* ductility?

Where is iron chiefly found?

By what substance is it generally mineralized?

What is the effect *of* hot iron *on* water?

What is the chemical name, *and* composition *of the* rust *of iron?*

Which, among the salts of iron, *is the* most *important to the* arts?

What is the *compositon* of writing INK?

Why does the addition of *iron filings* to INK destroy its *colour?*

Why is ink decomposed by age?

What is the composition of STEEL?

Why does iron occupy less space *in the* fluid *than in the* solid *form ?*

NICKEL.

What is said of the *malleability* of NICKEL ?
What is its specific gravity ?
In what respect does it resemble iron ?
What is the principal ore *of this metal ?*
What use do the Chinese make of this metal ?

TIN.

What is the *specific gravity* of tin ?
What is said of its ductility and malleability ?
What is the name of the alloy of TIN and COPPER ?
What is made of the amalgam *of* tin *and* mercury ?
What is the process of TINNING IRON ?

LEAD.

What is the *specific gravity* of LEAD ?
What is said of the oxidation *of* lead ?
How is RED LEAD prepared ?
How is red lead most easily reduced to its metallic state ?
What is said of the *action* of WATER on this metal ?
Under what circumstances does sulphuric acid *act on lead ?*
How is patent yellow *prepared ?*
What is the process for preparing WHITE LEAD ?
How is sugar of lead *made ?*

ZINC.

What is the name of the ore *from which Zinc is obtained ?*
What is said of the MALLEABILITY of this metal ?
How may this metal be burned *in the open air ?*
What salt of this metal is best known and most useful ?
What alloy of this metal is most important ?

BISMUTH.

What is the colour of BISMUTH ?
What is its SPECIFIC GRAVITY ?
How is the white oxide *of bismuth prepared ?*
Why is bismuth peculiarly useful in the composition of printing types ?

ANTIMONY.

What is the colour, and what are the other external properties of ANTIMONY?

What is the effect when vapour of water is brought in contact with ignited antimony?

What is said of the acids of this metal?

How is glass of antimony prepared?

What is the composition of TARTAR EMETIC?

Give some account of tellurium *and* selenium?

ARSENIC.

How may METALLIC ARSENIC be procured from the WHITE OXIDE?

By what particular smell *is arsenic distinguished?*

In what way can this metal be detected by metallic copper?

What is said of the poisonous qualities *of this metal?*

In what respect do the oxides of this metal fulfil the functions of an acid.

COBALT.

What is the colour and *specific gravity* of COBALT?

What is said of its fusibility?

What are the principal uses *of this metal?*

How is sympathetic ink *prepared from this metal?*

What peculiar properties has this ink?

MANGANESE.

Does this metal ever occur in the metallic state?

What curious properties has this metal?

What is the mineral camelion?

What is the principal use of the BLACK OXIDE of *manganese?*

CHROME.

What are the uses of chrome?

In what state is this metal found?

Give some account of molybdenum. uranium, titanium, columbium, and cerium.

ON THE EARTHS.

What are the names of the ALKALINE EARTHS?

What are the names of the SIMPLE EARTHS?

What is said about the *metallic bases* of the EARTHS?

What are the colours *of the* pure *earths?*

BARYTES.

How may pure barytes *be obtained?*

What are the qualities *of this earth?*

What are the uses *of this earth?*

What is the base of barytes called?

In what state is this earth found native?

What is the metallic base of this earth called?

What is the most obvious distinction between this earth and barytes?

LIME.

What is the *form* under which LIME exists in the greatest abundance?

How is QUICKLIME prepared?

How do you account for the HEAT produced by the *slacking* of lime?

In what proportion is lime soluble in water?

What is said of lime as a TEST for *carbonic acid?*

What are the principal USES of lime?

What is the base of lime called?

MAGNESIA.

How is MAGNESIA procured?

What are the USES of magnesia?

What are the forms *in which it is used in* medicine?

What is the metallic base of this earth called?

Has this metal ever been obtained?

SILEX.

What are the *stones* in which SILEX is chiefly found?

Describe the mode of obtaining this earth.

W*hat is the* colour *and* taste *of silex?*

W*hat are the acids which act on silex?*

What are the USES of this earth?

ALUMINE.

From whence does this earth derive its name?

Describe the process of obtaining this earth.

What is said of the existence of the *earth* in *soils*?

W*hat precious stones are composed of alumine?*

What USE is made of this earth in the ARTS?

Give some account of Zircon, Glucine, Ittria, *and* Thorina.

ON THE ALKALIES.

What are the *general properties* of the ALKALIES?

What are the names *of the alkalies?*

Why are the three first called fixed?

Why is ammonia *called the* volatile alkali?

POTASH.

From whence does POTASH derive its *name?*

How is POTASH obtained?

What is salt of tartar?

What is salt of wormwood?

How do these salts differ from common potash?

What are the principal USES of potash?

In how many proportions *does* carbonic acid *combine with potash?*

What are the *names* of these SALTS ?

What is the *composition* of POTASH ?

How was the decomposition of potash effected?

How do you account for the decomposition of potash by the galvanic battery?

How is pure *or* caustic *potash prepared?*

How does this differ from the carbonate of potash?

SODA.

How is SODA prepared ?

How does SODA differ from POTASH ?

What is the composition of BORAX ?

What is the composition of SEA-SALT ?

How is SODA obtained from the sulphate of soda ?

In what respects does SODA resemble POTASH ?

How does SOAP made with these two alkalies differ ?

What is said of the metals potassium *and* sodium ? *What is their specific gravity?*

What is the effect *when they come in contact with water?*

On what principle do you account for the COMBUSTION of these METALS when thrown on WATER ?

What proof is there that bases of potash and soda are metals?

LITHIA.

What is the history of LITHIA ?

In what respect does lithia resemble the other alkalies?

How is this alkali *distinguished from* potash *and soda?*

AMMONIA.

In what *form* does PURE AMMONIA exist ?

How is AMMONIA obtained ?

How may ammonia be retained and examined without a mercurial bath?

What effect does this gas have on flame?

How is SPIRIT OF HARTSHORN prepared ?

What is ammoniated alcohol?

What is said of SAL AMMONIAC ?

How is this SALT prepared ?

Explain the *principles* on which the formation of SAL AMMONIAC depends during this process.

Is ammonia a simple *or* compound *body?*

What evidence is there that ammonia has a metallic basis?

ON THE ACIDS.

Define what is meant by the term ACID.

With what substances do the ACIDS combine to form SALTS ?

Are all the acids sour ?

How are the acids formed?

What substances are called ACIDIFIABLE BASES ?

What is said of the combination of BASES with several DOSES of OXYGEN ?

What ACIDS are formed by the union of SULPHUR with oxygen?

From what are the PECULIAR PROPERTIES of the acids and their NAMES derived ?

How do you know by the NAME of an ACID, what proportion of OXYGEN it contains ?

When a base has combined with its FULL PROPORTION of oxygen, how does the NAME of the acid END ?

How does the NAME of the acid END when the base has combined with only ONE proportion of oxygen ?

Mention an instance where a base forms an OXIDE with the FIRST proportion of oxygen and an ACID with the SECOND.

Is every acid capable of uniting with each of the alkalies, earths, and metallic oxides ?

How many distinct ingredients *does a* salt *contain ?*

What would be the NAME of a SALT composed of *sulphuric acid* and *potash ?*

Do the acids ending in ous *and those ending in* ic *form similar salts with the same base ?*

How do the names of the salts end, which are formed with an acid, ending in ous ?

How do they end when formed of an acid ending in ic ?

When the ACID predominates in the composition of a SALT, how is this denoted ?

When the BASE predominates, how is it known ?

What is the composition of NITRATE of POTASH ?

What would be the *name* of a salt composed of MURIATIC ACID and AMMONIA ?

Into how many CLASSES do the acids admit of being divided ?

What is the ACIDIFYING principle among all the acids ?

MINERAL ACIDS.

SULPHURIC ACID. How is SULPHURIC ACID formed ?

What acid is formed when sulphur *is burned in* common air?

What acid is formed when it *is burned in* oxygen gas ?

What is the cause of this difference ?

What is the mode of manufacturing this acid ?

How are the SULPHATES formed ?

By what class of substances is sulphuric acid decomposed ?

How does charcoal decompose this acid ?

What is the composition of this acid in its dry state ?

SULPHUROUS ACID. *What is the form under which this acid exists ?*

How is this acid produced?

What are the properties of this gas?

How is its BLEACHING property shown?

What is said of its ACTION on metalic oxides?

How is this property of reviving metallic oxides explained?

NITRIC ACID. From what substance, and by what process is NITRIC ACID obtained?

What is the form of pure nitric acid?

What is said of the effect of light *on this acid?*

How does this acid act on combustibles?

Explain the reason *why it will* inflame charcoal *and oil of* turpentine, *when other acids do not.*

What is AQUA FORTIS?

What are the SALTS called which this acid forms with the bases?

NITROUS ACID. How is NITROUS ACID procured?

In what form *does it exist?*

How do you distinguish NITRIC, and NITROUS acids from each other?

CARBONIC ACID. What is the form of the CARBONIC ACID?

How may this acid be prepared by combustion?

What is the TASTE of this acid?

What other *proof* is there, that this gas is composed of CARBON and OXYGEN, besides the union of these substances by combustion?

MURIATIC ACID. From what SUBSTANCE, and by what process is this ACID obtained?

Explain the use of the several parts of the apparatus.

What are the *properties* of LIQUID MURIATIC ACID?

What are the *names* of the SALTS formed by this *acid?*

BORACIC ACID. *From what substance is this acid obtained?*

What is the process?

What peculiar effect does this acid have on flame?

What are the names of the salts compounded of this acid?

PHOSPHORIC ACID. *How is phosphoric acid procured?*

Explain the rationale *of its production?*

What are the properties of this acid?

What are the SALTS formed with this ACID called?

What is said of NATURAL PHOSPHATES?

Do plants contain this acid? What *consequences* are said, sometimes to happen from its existence in CHARCOAL?

PHOSPHORUS ACID. *How is this acid produced?*

What is the RATIONALE of its formation?

How are these salts changed in phosphates?

What are the SALTS called of which the acid forms a part?

ARSENIC ACID. How is ARSENIC ACID formed? What is said of its POISONOUS qualities?

What are its SALTS called?

ANTIMONIOUS and ANTIMONIC ACIDS. *Give some account of these acids.*

CHROMIC ACID. What is the form and colour of CHROMIC ACID?

How is this acid obtained?

What are the SALTS formed with this acid called?

MOLYBDIC and MOLYBDOUS ACIDS. *What are the bases of these acids?*

FLUORIC ACID. What is the *substance* from which this ACID is obtained?

Describe the process for obtaining it.

What SINGULAR, and CURIOUS property has this acid?

For what purpose is the FLUORIC ACID used?

Describe the method of ETCHING on glass.

ACETIC ACID. What is OXALIC ACID?

How does this ACID differ from VINEGAR?

How is VINEGAR made?

Why does CIDER, or WINE become ACID by exposure to the AIR?

What is said of WOOD vinegar?

How may PURE acetic acid be obtained?

What are the properties of pure acetic acid?

OXALIC ACID. *How is this acid obtained?*

What is the process of obtaining this acid from sugar by means of nitric acid?

What is the USE of OXALIC ACID?

What are the names of the salts, formed of this acid?

TARTARIC ACID. Give some account of TARTARIC ACID.

From what substance, and how, is this acid obtained? Describe the PROCESS and point out the CHEMICAL CHANGES which take place in its progress.

To what USE is this acid applied?

What is the composition of the SODA POWDERS?

What occasions the EFFERVESCENCE when these POWDERS are thrown into WATER?

GALLIC ACID. *What substance contains this acid in the greatest abundance?*

What is said of the property of this ACID to PRECIPITATE the METALS from their solutions?

How is INK made?

CITRIC ACID. What are the FRUITS which contain the

CITRIC ACID in the greatest abundance ?

How is this acid obtained ?

What is the form of this acid ?

What are its USES ?

MALIC ACID. *What is said of this acid ?*

PYROLIGNEOUS ACID. From what is this ACID obtained ?

What is the process of manufacturing it ?

What are the PECULIAR and USEFUL properties of this acid ?

What is the difference between the PYROLIGNEOUS and ACETIC acids ?

What is said of its powers of PRESERVING MEAT ?

PRUSSIC ACID. Is this an ANIMAL, or VEGETABLE acid ?

Describe the process of preparing it ?

Point out the CHEMICAL CHANGES which take place during the process.

What is the colour, and what are the qualities of this acid ?

What are the USES of the prussic acid ?

SEBACIC ACID. What are the substances from which the SEBACIC ACID are obtained ?

ON THE SALTS.

Give a definition of SALT.

What part of the salt is called the BASE ?

When is an acid said to be SATURATED ?

When is the acid and base said to be NEUTRALIZED ?

What does the preposition SUPER denote when prefixed to the name of a salt ?

How does sub-*carbonate of soda differ from the carbonate ?*

What is said of saturating water with several kinds of salt at the same time ?

SULPHATES.

What are some of the distinctive characters of the SULPHATES ?

SULPHATE OF SODA. *How is* sulphate of soda *formed ?*

Does the acid, or alkali predominate in this salt ?

What is the composition of this salt ?

SULPHATE OF BARYTES. *What is one of the most remarkable properties of this salt ?*

How will you treat the sulphate of barytes to afford the solar phosphori ?

What is the composition of this salt ?

SULPHATE OF LIME. Where is SULPHATE of LIME found, and under what NAME is it generally known ?

What are its USES ?

What per cent. of water does this salt contain ?

SULPHATE OF MAGNESIA. What is the COMMON NAME of this salt.

What is the PROCESS, by which this salt is obtained?

Describe some of its properties.

Of what is it composed, and what are the proportions?

What are its USES?

SULPHATE OF ALUMINE. What is the COMMON NAME of this salt?

Where is it found?

Describe the DIFFERENT METHODS of obtaining it.

Describe the process of making HOMBERG'S PYROPHORUS.

What are the peculiar properties *of this substance?*

Describe the chemical changes which the sugar and alum undergo during this process.

NITRATES.

What are the distinctive characters of the NITRATES?

NITRATE OF POTASH. What is the COMMON NAME of this salt?

Where is nitre found?

What is the MODE OF OBTAINING NITRE?

What is said of the nitre found in the state of Kentucky?

Describe an ARTIFICIAL NITRE BED.

What CHEMICAL AGENCIES are involved in the FORMATION of nitre in these beds?

What are the component parts of this salt?

What is obtained by the DISTILLATION of nitre?

What is said of the DECOMPOSITION of nitre by means of SULPHUR?

How is GUNPOWDER prepared?

Describe the mode of preparing fulminating powder.

NITRATE OF AMMONIA. Describe the METHOD of PREPARING this salt?

What are the USES of this salt?

MURIATES.

What are the distinctive characters of the MURIATES?

MURIATE OF SODA. What is the COMMON NAME of this salt?

What is the PROPORTION of common salt in SEA WATER?

Describe the salt mine at Cheshire.

Mention the principal places where great quantities of this salt are found.

What quantity of salt is estimated to have been made yearly from SALT SPRINGS in the United States?

By what method is muriate of soda extracted from SEA WATER?

What change does this salt undergo on being ignited in a crucible with charcoal?

What are the component parts of this salt?

MURIATE OF LIME. *How is muriate of lime prepared?*

What peculiar property of this salt is mentioned?

OXYMURIATES.

What are the distinctive properties of the oxymuriates, or *chlorates?*

CHLORATE OF POTASH. How is this SALT prepared?

What CAUTION is to be observed in preparing this salt?

When this salt is distilled, what is the product?

In what peculiar *manner can* combustion *be effected by means of this salt?*

What CAUTION is to be observed in regard to mixtures of chlorate of potash and combustibles?

CARBONATES.

What are the characteristic properties of the CARBONATES?

CARBONATE OF LIME. What is the common NAME of this salt?

How is QUICKLIME prepared?

What acid is given out when carbonate of lime is mixed with any of the mineral acids?

What is the experiment proving the solubility of lime in carbonic acid?

How is it proved that lime absorbs carbonic acid from the atmosphere?

CARBONATE OF POTASH. What is the common NAME of this salt?

What is said of the quantity of carbonic acid *absorbed by* pure potash?

What CHANGE is produced on the *potash* by this absorption?

By what method can you tell the *quantity of* CARBONIC ACID which a sample of potash contains?

What is the DIFFERENCE between *carbonate* and *bi-carbonate* of potash?

Describe the process *of making the* bi-carbonate.

What proportions of alkali and acid do each of these salts contain?

CARBONATE OF SODA. *How is soda obtained?*

There are two distinct salts of soda, describe the difference between them.

ON THE COMPOUND GASES.

CARBURETTED HYDROGEN. What is the composition of this GAS?

What difference is there between the several varieties of this gas?

How is carburetted hydrogen PROCURED?

On what does the difference of SPECIFIC GRAVITY in these gases depend?

How is the GAS used in LIGHTING STREETS, obtained?

By what simple experiment can an example of gas-lights be shown?

By what process can this gas be obtained from alcohol?

CARBONIC OXIDE. How does this gas DIFFER from CARBONIC ACID?

How is carbonic oxide OBTAINED?

Explain why CARBONIC OXIDE is obtained by this process, and not CARBONIC ACID?

Is this an inflammable gas?

How is it proved that this gas contains NO HYDROGEN?

NITROUS OXIDE. What is the COMPOSITION of this GAS?

What is the name of the salt from which this gas is obtained?

What is the PROCESS of obtaining it?

Describe the SIMPLE UTENSILS with which it may be PROCURED and BREATHED.

ON VEGETATION.

What are the ELEMENTARY SUBSTANCES of which VEGETABLES are composed?

What are the essential ORGANS of plants?

What change does the FARINACEOUS SUBSTANCE of seeds undergo during their *germination?*

What circumstances are necessary to the HEALTHY GERMINATION of seeds?

How is it shown that seeds will NOT GERMINATE without AIR?

What is said of the germination of seeds in the exhausted receivers of an air pump?

What effect does OXYGEN have on the GERMINATION of seeds?

What is said of Van Helmont's willow?

What is ascertained concerning the GROWTH of PLANTS in PURE WATER?

How is it proved that plants absorb matter from the soil?

What particular INGREDIENTS must a soil contain in order to make it productive?

Is it necessary that the FOOD of plants should be SOLUBLE in WATER?

What CHANGE does the SAP undergo in the LEAVES?

What part of a plant performs the office of perspiration?

What facts are known concerning the ABSORPTION of CARBONIC ACID by the LEAVES of plants?

Will plants live in pure carbonic acid?

What do plants EMIT while they ABSORB carbonic acid?

How do you account for the fact that plants ABSORB CARBONIC ACID and at the same time GIVE OUT OXYGEN?

When a plant is exposed to the rays of the sun, under water, what effect does the water have on the plant?

How is it proved that plants refuse to emit oxygen, unless carbonic acid be present?

What DIFFERENT OFFICES do the leaves of plants perform during the NIGHT and during the DAY?

What is said of the absorption of water by the leaves of plants?

What circumstances show that the leaves absorb water?

What other agent besides heat, oxygen, and moisture, does vegetation require?

How do plants show their disposition to enjoy the LIGHT?

Why do trees standing near together grow taller than those which are scattered?

What effect does light or darkness have on the quantity of carbon which plants contain?

Why do not plants growing in the dark, contain the ordinary quantity of oil?

What are the PRODUCTS of vegetables, when submitted to DESTRUCTIVE DISTILLATION?

What are each of these products composed of?

When a vegetable substance contains *more* OXYGEN, than is necessary to form WATER with the HYDROGEN present, what is the result?

When a vegetable substance contains *less* OXYGEN, than in the proportion to form WATER with the HYDROGEN present, what then is formed?

In what proportion do the elements, hydrogen and oxygen exist, in SACCHARINE and MUCILAGINOUS substances?

What are the INGREDIENTS of plants?

How can the INGREDIENTS of plants be SEPARATED from each other?

What are the solvents *made use of for this purpose?*

GUM. What is the proper solvent of GUM?

When GUM is submitted to destructive distillation, what is the product?

SUGAR. How is SUGAR obtained?

What is the process of PURIFYING RAW SUGAR?

What is the method of whitening sugar?

What is the composition of sugar?

STARCH. *How is* starch *obtained, and from what substances?*

What is the most characteristic property of starch ?

How may STARCH be converted into SUGAR ?

GLUTEN. *How may gluten be obtained ?*

What are the properties of gluten ?

What is the proportion of gluten in wheat ?

EXTRACTIVE MATTER. What is meant by EXTRACTIVE MATTER ?

How is it obtained ?

TANNIN. What are the substances which chiefly contain TANNIN ?

How may tannin be obtained ?

What is the principal USE of tannin ?

How does tannin render LEATHER impervious to water ?

COLOURING MATTER. *What is said of the colouring principle ?*

How have COLOURS been divided in reference to their employment in DYEING ?

What do ADJECTIVE COLOURS require to fix them ?

What is the intervening substance between the cloth and the colouring called ?

FIXED OILS. In what PARTS of plants are FIXED OILS found ?

How are these oils obtained ?

What changes do these oils undergo in air ?

What causes RANCIDITY in oils ?

What is the composition of the fixed oils ?

VOLATILE OILS. How are the VOLATILE OILS obtained ?

What is the proper solvent *for these oils ?*

What are their principal uses ?

When these oils are adulterated with fixed oils, *how may the fraud be detected ?*

ON FERMENTATION, &c.

What is FERMENTATION ? Define the term.

What CONDITIONS are necessary for this process ?

What are the phenomena attending vinous fermentation ?

What GAS is GENERATED and makes its escape during the process ?

What is the PRINCIPAL SUBSTANCE concerned in vinous FERMENTATION ?

In the production of beer, where does the sugar come from ?

What changes does fermentation produce on the fermented liquor ?

What is said concerning the PRODUCTION of ALCOHOL by DISTILLATION ?

What gives the PECULIAR flavour to DISTILLED SPIRITS?

How is ALCOHOL obtained?

What is the composition of alcohol?

ETHER. How is ETHER procured?

How do the various ethers differ from each other; and on what does this difference depend?

How is SULPHURIC ETHER obtained?

What are the QUALITIES of sulphuric ether?

What is the composition of sulphuric ether?

How is NITRIC ETHER prepared?

What are some of the qualities of nitric ether?

ON ELECTRO-CHEMISTRY.

When will two electrified PITH BALLS REPEL, and when will they ATTRACT each other?

What is the difference between CONDUCTORS and NON-CONDUCTORS of electricity?

What is the difference between ELECTRICS and NON-ELECTRICS?

What substances are conductors and what are non-conductors of electricity?

When two ELECTRICS are rubbed together, what is the DIFFERENCE in their ELECTRICAL STATES?

In what do the positive and negative electrical states consist?

When is a conductor said to be insulated?

GALVANIC ELECTICITY.

What are the substances capable of exhibiting GALVANIC PHENOMENA?

What DIFFERENCE is there between the CONDITIONS necessary to excite COMMON ELECTRICITY and those necessary to excite GALVANISM?

In the experiment with the two metals and the tongue, what galvanic principles are involved?

Describe a galvanic PILE and explain the PRINCIPLES of its action?

In what respects must two METALS DIFFER, as a necessary CONDITION to the extrication of galvanic power?

How may the same metal be made the positive or negative side respectively?

What serves as a CONDUCTOR of the galvanic power from plate to plate in the VOLTAIC PILE?

Describe the construction of the galvanic trough, and explain its principles of action.

How may a galvanic battery be constructed by means of glasses and plates of metal?

A

VOCABULARY

OF

CHEMICAL TERMS.

A

Acetates. Compounds formed by the combinations of a base with acetic acid.

Acids. Compounds formed by the combination of oxygen with certain elementary bodies, forming in general a class of substances which are sour to the taste, and which unite with alkalies, and metallic oxides to form salts.

Aeriform fluids. Elastic fluids. Atmospheric air, and the gases are of this kind. Their aeriform state is owing to the caloric with which their bases are combined.

Affinity, *chemical*. A term used to express that peculiar propensity which substances of different kinds have to unite with each other, as acids, and alkalies, &c.

——— *of aggregation*. That force is so called by which substances of the same kind tend to unite, without changing their qualities.

——— *of composition*. The force by which substances of different kinds combine, and form a third, which differs from either of the two first, before the combination. Thus muriatic acid and soda form common salt.

Albumen. Coagulable lymph. It is contained in animal substances, as the serum of the blood. The white of eggs is albumen.

Alcohol. Rectified spirit of wine. It is always the same, from whatever kind of spirit it is distilled.

Alkalies. Peculiar substances which have a caustic burning taste, and a strong tendency to combination, particularly with acids, and with water.

Alloys. A combination of any two metals, except mercury. Brass is an alloy of copper and zinc.

Amalgam. A mixture of mercury with any other metal.

Analysis. Separation of the constituent parts of compounds, for the purpose of detecting their composition. This is done by *re-agents*.

Annealing. Rendering substances tough, which before were brittle. The metals are annealed by heating them red hot, and then cooling them gradually.

Arseniates. Salts formed by the combination of a base with the arsenic acid.

Azote. This name is given by the French chemists to *nitrogen*, which see.

B.

Balsams. Certain aromatic resinous substances, which are obtained from some trees by incisions. Of this kind are the Canada balsam, the balsam of Copavia, the balsam of Tolu, &c.

Barometer. An instrument which shows the variation of the pressure of the atmosphere, by the rise or fall of a column of mercury in a glass tube attached to a graduated plate.

Base. A chemical term, usually applied to denote the earth, the alkali, or the metal which is combined with an acid to form a salt.

Baths. Vessels for distillation or digestion, contrived to transmit heat gradually or regularly.

——— *sand.* Vessels filled in part with dry sand, in which those retorts are placed which require a greater heat than can be given by boiling water. In large works, iron plates are used instead of vessels of capacity. They are often called *sand heats.*

——— *water.* Vessels of boiling water, in which other vessels containing the matters to be distilled or digested are placed, in order that the same heat may be kept up throughout the whole of any particular process.

Benzoates. Salts formed by the combination of any base with the benzonic acid.

Blow-pipe. An instrument to increase and direct the flame of a lamp for the analysis of minerals, and for other chemical purposes.

Borates. Salts formed by the combination of any base with the acid of borax.

C.

Calcareous. A chemical term formerly applied to describe chalk, marble, and all other combinations of lime with carbonic acid.

Caloric. The chemical term for the matter of heat.

——— *free.* Is caloric in a separate state, or, if attached to other substances, not *chemically* united with them.

——— *latent.* Is the term made use of to express that portion of caloric which is chemically united to any substance, so as to become a *part* of the said substance.

Camphorates. Salts formed by the combination of any base with the camphoric acid.

Capillary. A term usually applied to the rise of the sap in vegetables, or the rise of any fluid in very small tubes; owing to a peculiar kind of attraction, called capillary attraction.

Carbon. The basis of charcoal.

Carbonates. Salts formed by the combination of any base with carbonic acid.

Carburets. Compound substances, of which carbon forms one of its constituent parts. Thus plumbago, which is composed of carbon and iron, is called carburet of iron.

Charcoal. Wood burnt in close vessels: it is an oxide of carbon, and generally contains a small portion of salts and earth. Its carbonaceous matter may be converted by combustion into carbonic acid gas.

Chlorine. A name lately given to the substance usually called oxymuriatic acid.

Chlorates. Salts formed by the union of the chloric acid with the salifiable bases.

Chromates. Salts formed by the combination of any base with the chromic acid.

Citrates. Salts formed by the combination of any base with citric acid.

Coal. A term applied to the residum of any dry distillation of animal or vegetable matters.

Cohesion. A force inherent in all the particles of all the substances, excepting light and caloric, which prevents bodies from falling in pieces.

Columbates. Salts formed by the combination of any base with the columbic acid.

Combination. A term expressive of a true *chemical* union of two or more substances; in opposition to mere mechanical mixture.

Combustibles. Certain substances which are capable of combining more or less rapidly with oxygen. They are divided by chemists into simple and compound combustibles.

Combustion. The act of absorption of oxygen by combustible bodies from atmospheric or vital air.

Crystallization. An operation of nature, in which various earths, salts, and metallic substances, pass from a fluid to a solid state, assuming certain determinate geometrical figures.

——— *water of.* That portion which is combined with salts in the act of crystallizing, and becomes a *component* part of the said saline substances.

D.

Decomposition. The separation of the constituent principles of compound bodies by chemical means.

Deflagration. The vivid combustion that is produced whenever nitre, mixed with an inflammable substance, is exposed to a red heat. It may be attributed to the extrication of oxygen from the nitre, and its being transferred to the inflammable body; as any of the nitrates or oxygenized muriates will produce the same effect.

Deliquescence of solid saline bodies, signifies their becoming moist, or liquid, by means of water which they absorb from the atmosphere in consequence of their great attraction for that fluid.

Deoxidize. To deprive a body of oxygen.

Detonation. An explosion with noise. It is most commonly applied to the explosion of nitre when thrown upon heated charcoal.

Digestion. The effect produced by the continued soaking of a solid substance in a liquid, with the application of heat.

Distillation. A process for separating the volatile parts of a substance from the more fixed, and preserving them both in a state of separation.

Ductility. A quality of certain bodies, in consequence of which they may be drawn out to a certain length without fracture.

E.

Edulcoration. Expressive of the purification of a substance by washing with water.

Effervescence. An intestine motion which takes place in certain bodies, occasioned by the escape of a gaseous substance.

Efflorescence. A term commonly applied to those saline crystals which become pulverulent on exposure to the air, in consequence of the loss of a part of the water of crystallization.

Elasticity. A force in bodies, by which they endeavour to restore themselves to the posture from whence they were displaced by an external force.

Elastic fluids. A name sometimes given to vapours and gases. Vapour is called an *elastic* fluid; gas, a *permanently* elastic fluid.

Elements. The simple, constituent parts of bodies which are incapable of decomposition; they are frequently called principles. See *Simple Substances.*

Empyreuma. A peculiar and indiscribable disagreeable smell, arising from the burning of animal and vegetable matter in close vessels.

Ethers. Volatile liquids formed by the distillation of some of the acids with alcohol.

Evaporation. The conversion of fluids into vapour by heat. This appears to be nothing more than a gradual solution of the aqueous particles in atmospheric air, owing to the chemical attraction of the latter for water.

Eudiometer. An instrument invented by Dr. Priestley for determining the purity of any given portion of atmospheric air. The science of investigating the different kinds of gases is called *eudiometry.*

F.

Fermentation. A peculiar spontaneous motion, which takes place in all vegetable matter when exposed for a certain time to a proper degree of temperature.

Fibrine. That white fibrous substance which is left after freely washing the coagulum of the blood, and which chiefly composes the muscular fibre.

Flowers. In chemical language, are solid dry substances reduced to a powder by sublimation. Thus we have flowers of arsenic, of sal ammoniac, of sulphur, &c. which are arsenic, sal ammoniac, and sulphur unaltered except in appearance.

Fluates. Salts formed by the combination of any base with fluoric acid.

Fluidity. A term applied to all liquid substances. Solids are converted to fluids by combining with a certain portion of caloric.

Flux. A substance which is mixed with metallic ores, or other bodies to promote their fusion; as an alkali is mixed with silex, in order to form glass.

Fulmination. Thundering or explosion with noise. We have fulminating silver, fulminating gold, and other fulminating powders, which explode with a loud report, by friction, or when slightly heated.

Fusion. The state of a body which was solid in the temperature of the atmosphere, and is now rendered fluid by the artificial application of heat.

G.

Gallates. Salts formed by the combination of any base with gallic acid.

Galvanism. A new science which offers a variety of phenomena, resulting from different conductors of electricity, placed in different circumstances of contact.

Gas. All solid substances, when converted into permanently elastic fluids by caloric, are called gases.

Gaseous. Having the nature and properties of gas.

Gasometer. A name given to a variety of utensils and apparatus contrived to measure, collect, preserve, or mix the different gases. An apparatus of this kind is also used for the purpose of administering pneumatic medicines.

Gelatine. A chemical term for animal gelly. It exists particularly in the tendons and the skin of animals.

Gluten. A vegetable substance somewhat similar to animal gelatine. It is the gluten in wheat flour which gives it the property of making good bread, and adhesive paste. Other grain contains a much less quantity of this nutritious substance.

Grain. The *smallest* weight made use of by chemical writers. Twenty grains make a scruple; 3 scruples a drachm; 8 drachms, or 480 grains, make an ounce; 14 ounces, or 5760 grains, a pound troy. The *adroirdupois* pound contains 7000 grains.

Granulation. The operation of pouring a *melted* metal into water, in order to divide it into small particles for chemical purposes. Tin is thus granulated by the dyers before it is dissolved in the proper acid.

Gravity specific. This differs from absolute gravity in as much as it is the weight of a given *measure* of any solid or fluid body, compared with the *same measure* of distilled water. It is generally expressed by decimals.

Gums. Mucilaginous exudations from certain trees. Gum consists of lime, carbon, oxygen, hydrogen, and nitrogen, with a little phosphoric acid.

H.

Heat, matter of. See Caloric.

Hermetically. A term applied to the closing of the orifice of a glass tube, so as to render it air-tight. Hermes, or Mercury, was formerly supposed to have been the inventor of chemistry; hence a tube which was closed for chemical purposes, was said to be Hermetically sealed. It is usually done by melting the end of the tube by means of a blow-pipe.

Hydrogen. A simple substance; one of the constituent parts of water.

——— *gas.* Solid hydrogen united with a large portion of caloric. It is the lightest of all the known gases. Hence it is used to inflate balloons. It was formerly called inflammable air.

Hydro-Carbonates. Combinations of carbon with hydrogen are described by this term. Hydro-carbonic gas is procured from moistened charcoal by distillation.

Hydrogenized sulphurets. Certain bases combined with sulphuretted hydrogen.

Hydro-Oxydes. Metallic oxides combined with water.

Hydrometers. Instruments for ascertaining the specific gravity of spirituous liquors or other fluids.

Hygrometers. Instruments for ascertaining the degree of moisture in atmospheric air.

Hyperoxygenised. A term applied to substances which are combined with the largest possible quantity of oxygen. We have muriatic acid, oxygenized muriatic acid, and hyperoxygenized muriatic acid. The latter can be exhibited only in combination.

I.

Inflammation. A phenomenon which takes place on mixing certain substances. The mixture of oil of turpentine with strong nitrous acid, is an instance of this peculiar chemical effect.

Infusion. A simple operation to procure the salts, juices, and other virtues of vegetables by means of water.

Intermediates. A term made use of when speaking of chemical affinity. Oil, for example, has no affinity for water unless it be previously combined with an alkali; it then becomes soap, and the alkali is said to be the *intermedium* which occasions the union.

K.

Kali. A genus of marine plants which are burnt to procure mineral alkali by afterwards lixiviating the ashes.

L.

Laboratory. A room fitted up with apparatus for the performance of chemical operations.

Lactates. Salts formed by the combination of any base with lactic acid.

Lakes. Certain colours made by combining the colouring matter of cochineal, or of certain vegetables, with pure alumine, or with oxide of tin, zinc, &c.

Lamp, Argand's. A kind of lamp much used for chemical experiments. It is made on the principle of a wind furnace, and thus produces a great degree of light and heat without smoke.

Lens. A glass, convex on both sides, for concentrating the rays of the sun. It is employed by chemists in fusing refractory substances which cannot be operated upon by an ordinary degree of heat.

Levigation. The grinding down of hard substances to an impalpable powder on a stone with a maller, or in a mill adapted to the purpose.

Litharge. An oxide of lead which appears in a state of vitrification. It is formed in the process of separating silver from lead.

Lixiviation. The solution of an alkali or a salt in water, or in some other fluid, in order to form a lixivium.

Lixivium. A fluid impregnated with an alkali or with a salt.

Lute. A composition for closing the junctures of chemical vessels to prevent the escape of gas or vapour in distillation.

M.

Maceration. The steeping of a solid body in a fluid in order to soften it, without impregnating the fluid.

Malates. Salts formed by the combination of any base with malic acid.

Malleability. That property of metals which gives them the capacity of being extended and flattened by hammering. It is probably occasioned by latent caloric.

Massicot. A name given to the *yellow* oxide of lead, as minium is applied to the *red* oxide.

Matrass. Another name for a bolt-head; which see.

Menstruum. The fluid in which a *solid* body is dissolved. Thus water is a menstruum of salts, gums, &c. and spirit of wine for resins.

Metallic Oxides. Metals combined with oxygen. By this process they are generally reduced to a pulverulent form; are changed from combustible to incombustible substances; and receive the property of being soluble in acids.

Mineral. Any natural substance of a metallic, earthy, or saline nature, whether simple or compound, is deemed a mineral.

Mineralizers. Those substances which are combined with metals in their ores; such as sulphur, arsenic, oxygen, carbonic acid, &c.

Mineralogy. The science of fossils and minerals.

Mineral Waters. Waters which hold some metal, earth, or salt, in solution. They are frequently termed Medicinal Waters.

Molybdates. Salts formed by the combination of any base with the molybdic acid.

Mordants. Substances which have a chemical affinity for particular colours; they are employed by dyers as a bond to unite the colour with the cloth intended to be dyed. Alum is of this class.

Mucilage. A glutinous matter obtained from vegetables, transparent and tasteless, soluble in water, but not in spirit of wine. It chiefly consists of carbon and hydrogen, with a little oxygen.

Mucites. Salts formed by the combination of any base with the mucous acid.

Muffle. A semi-cylindrical utensil, resembling the tilt of a boat, made of baked clay; its use is that of a cover to cupels in the assay furnace, to prevent the charcoal from falling upon the metal, or whatever is the subject of experiment.

Muriates. Salts formed by the combination of any base with muriatic acid.

N.

Natron. One of the names for mineral alkali, soda.

Neutralize. When two or more substances mutually disguise each other as an acid and alkali, they are said to neutralize one another.

Neutral Salts. A substance formed by the union of an acid with an alkali, an earth, or a metallic oxide, in such proportions as to saturate both the base and the acid.

Nitrates. Salts formed by the combination of any base with nitric acid.

Nitrogen. A simple substance, by the French chemists called azote. It enters into a variety of compounds, and forms more than three parts in four of atmospheric air.

O.

Ochres. Various combinations of the earths with oxide, or carbonate of iron.

Ores. Metallic earths or metals, which frequently contain several extraneous matters; such as sulphur, arsenic, &c.

Oxalates. Salts formed by the combination of any base with oxalic acid.

Oxide. Any substance combined with oxygen, in a proportion not sufficient to produce acidity.

Oxidize. To combine oxygen with a body without producing acidity.

Oxidizement. The operation by which any substance is combined with oxygen, in a degree not sufficient to produce acidity.

Oxygen. A simple substance composing the *greatest* part of water, and part of atmospheric air.

——*gas.* Oxygen converted to a gaseous state by caloric. It is also called vital air. It forms nearly one-fourth of atmospheric air.

Oxygenize. To acidify a substance by oxygen. Synonymous with Oxygenate; but the former is the better term.

Oxygenizement. The production of acidity by oxygen.

P.

Pellicle. A thin skin which forms on the surface of saline solutions and other liquors, when boiled down to a certain strength.

Phosphates. Salts formed by the combination of any base with phosphoric acid.

Phosphites. Salts formed by the combination of any base with phosphorous acid.

Phosphurets. Substances formed by an union with phosphorus. Thus we have phosphuret of lime, phosphuretted hydrogen, &c.

Plumbago. Carburet of iron, or the *black lead* of commerce.

Pneumatic. Any thing relating to the airs and gases.

——— *trough.* A vessel filled in part with water or mercury, for the purpose of collecting gases, so that they may be readily removed from one vessel to another.

Precipitate. Any matter which, having been dissolved in a fluid, falls to the bottom of the vessel on the addition of some other substance capable of producing a decomposition of the compound, in consequence of its attraction either for the menstruum, or for the matter which was before held in solution.

Precipitation. The chemical process by which bodies dissolved, mixed, or suspended in a fluid, are separated from that fluid, and made to gravitate to the bottom of the vessel.

Prussiates. Salts formed by the combination of any base with prussic acid.

Putrefaction. The last fermentative process of nature, by which organized bodies are decomposed so as to separate their principles, for the purpose of reuniting them by future attractions, in the production of new compositions.

Pyrites. An abundant mineral found on the English coasts, and elsewhere. Some are sulphurets of iron, and others sulphurets of copper, with a portion of alumine and silex. The former are worked for the sake of the sulphur, and the latter for sulphur and copper. They are also called Marcasites and Fire-stone.

——— *martial.* That species of pyrites which contains iron for its basis.

Pyrometer. An instrument invented by Mr. Wedgwood, for ascertaining the degrees of heat in furnaces and intense fires.

Pyrophori. Compound substances which heat of themselves, and take fire on the admission of atmospheric air.

Q.

Quartz. A name given to a variety of siliceous earths, often mixed with a small portion of metalic oxides. Rock crystal and the amethyst are species of quartz.

R.

Radicals. A chemical term for the *Elements* of bodies; which see.

——— *compound.* When the base of an acid is composed of two or more substances, it is said that the acid is formed of a *compound* radical. The sulphuric acid is formed with a *simple* radical; but the vegetable acids, which have radicals composed of hydrogen and carbon, are said to be acids with compound radicals.

Reagents. Substances which are added to mineral waters or other liquids as tests to discover their nature and composition. See *Test.*

Receivers. Globular glass vessels adapted to retorts, for the purpose of preserving and condensing the volatile matter raised in distillation.

Rectification, is nothing more than the re-distilling a liquid to render it more pure, or more concentrated, by abstracting a part of it.

Reduction. The restoration of metallic oxides to their original state of metals; which is usually effected by means of charcoal and fluxes.

Refining. The process of separating the perfect metals from other metallic substances.

Refrigeratory. A contrivance of any kind, which, by containing cold water, answers the purpose of condensing the vapour or gas that arises in distillation. A worm-tube is a refrigeratory.

Resins. Vegetable juices concreted by evaporation either spontaneously or by fire. Their characteristic is solubility in alcohol, and not in water. In seems that they owe their solidity chiefly to their union with oxygen.

Retort. A vessel in the shape of a pear, with its neck bent downwards, used in distillation; the extremity of which neck fits into that of another bottle called a receiver.

Rock-Crystal. Crystallized silex.

S.

Saccholates. Salts formed by the combination of any base with saccholatic acid.

Salifiable Bases. All the metals, alkalies, and earths, which are capable of combining with acids, and forming salts, are called salifiable bases.

Saline. Partaking of the properties of a salt.

Salts neutral. A class of substances formed by the combination to saturation of an acid with an alkali, an earth, or other salifiable bases.

——— *triple.* Salts formed by the combination of an acid with two bases or radicals. The tartrate of soda and potash (Rochelle salt) is an instance of this kind of combination.

Saponaceous A term applied to any substance which is of the nature or appearance of soap.

Saturation. The act of impregnating a fluid with another substance, till no more can be received or imbibed. A fluid which holds as much of any substance as it can dissolve, is said to be saturated with that substance. A solid may in the same way be saturated with a fluid.

Sebates. Salts formed by the combination of any base with sebacic acid.

Semi-Metal. A name formerly given to those metals which, if exposed to the fire, are neither malleable, ductile, nor fixed. It is a term not used by modern chemists.

Siliceous Earths. A term used to describe a variety of natural substances which are composed chiefly of silex; as quartz, flint, sand, &c.

Simple Substances. Synonymous with *Elements*; which see.

Smelting. The opperation of fusing ores for the purpose of separating the metals they contain, from the sulphur and arsenic with which they are mineralized, and also from other heterogeneous matter.

Solution. The perfect union of a solid substance with a fluid. Salts dissolved in water are proper examples of solution.

Spars. A name formerly given to various crystallized stones; such as the fluor spar, the adamantine spar, &c. These natural substances are now distinguished by names which denote the nature of each.

Stalactites. Certain concretions of calcareous earth found suspended like icicles in caverns. They are formed by the oozing of water, through the crevices, charged with this kind of earth.

Steatite. A kind of stone composed of silex, iron, and magnesia. Also called French chalk, Spanish chalk, and soap-rock.

Sub-Salts. Salts with less acid than is sufficient to neutralize their radicals.

Suberates. Salts formed by the combination of any base with the suberic acid.

Sublimation. A process whereby certain volatile substances are raised by heat, and again condensed by cold into a solid form. Flowers of sulphur are made in this way. The soot of our common fires is a familiar instance of this process.

Succinates. Salts formed by the combination of any base with the succinic acid.

Sulphates. Salts formed by the combination of any base with the sulphuric acid.

Sulphites. Salts formed by the combination of any base with the sulphurous acid.

Sulphurets. Combination of alkalies, or metals with sulphur.

Sulphuretted. A substance is said to be sulphuretted when it is combined with sulphur. Thus we say sulphuretted hydrogen, &c.

Super-Salts. Salts with an excess of acid, as the supertartrate of potass.

Synthesis. When a body is examined by *dividing* it into its component parts, it is called *analysis ;* but when we attempt to prove the nature of a substance by the *union* of its principles, the operation is called synthesis.

T.

Tartrates. Salts formed by the combination of any base with the acid of tartar.

Temperature. The absolute quantity of free caloric which is attached to any body occasions the degree of temperature of that body.

Test. That part of the cupel which is impregnated with litharge in the operation of refining lead. It is also the name of whatever is employed in chemical experiments, to detect the several ingredients of any composition.

Test-Papers. Papers impregnated with certain chemical re-agents ; such as litmus, tumeric, radish, &c. They are used to dip into fluids to ascertain by a change of colours, the presence of acids and alkalies.

Thermometer. An instrument to show the relative heat of bodies. Fahrenheit's thermometer is that chiefly used in England. Other thermometers are used in different parts of Europe.

Trituration. An operation whereby substances are united by friction. Amalgams are made by this method.

Tubulated. Retorts which have a hole at the top for inserting the materials to be operated upon withouf taking them out of the sand heat, are called *tubulated* retorts.

Tungstates. Salts formed by the combination of any base with tungstic acid.

V.

Vacuum. A space unocupied by matter. The term is generally applied to the exhaustion of atmospheric air by chemical or philosophical means.

Vapour. This term is used by chemists to denote such exhalations only as can be condensed and rendered liquid again at the ordinary atmospheric temperature, in opposition to those which are *permanently* elastic.

Vital Air. Oxygen gas. The empyreal or fire-air of Scheele, and the dephlogisticated air of Priestley.

Vitrification. When certain mixtures of solid substances, such as silex and an alkali, are exposed to an intense heat, so as to be fused, and become glass, they are then said to be vitrified, or to have undergone vitrification.

Vitriols. Salts formed with the sulphuric, formerly called vitriolic acid, and a base. Thus there was vitriol of iron, of copper, &c. These salts are now called sulphates.

Vitriolated Tartar. The old name for sulphate of potass.

Volatile Alkali. Another name for ammonia.

Volatile Salts. The commercial name for carbonate of ammonia.

Volatility. A property of some bodies which disposes them to assume the gaseous state. This property seems to be owing to their affinity for caloric.

Volume. A term made use of by modern chemists to express the space occupied by gaseous or other bodies.

U.

Union, Chemical. When a mere mixture of two or more substances is made, they are said to be mechanically united; but when each or either substance forms a component part of the product, the substances have formed a *chemical* union.

W.

Water. The most common of all fluids, composed of 79 parts of oxygen and 21 of hydrogen.

——*mineral*. Waters which are impregnated with mineral and other substances, are known by this appellation. These minerals are generally held in solution by carbonic, sulphuric, or muriatic acids.

Welding Heat. That degree of heat in which two pieces of iron or of platina may be united by hammering.

Wolfram. An ore of tungsten containing also manganese and iron.

Woulfe's apparatus. A contrivance for distilling the mineral acids and gaseous substances with little loss; being a train of receivers with safety-pipes, and connected together by tubes.

Z.

Zaffre. An oxide of cobalt mixed with a portion of siliceous matter. It is imported in this state from Saxony.

Zero. The point from which the scale of a thermometer is graduated Thus Celsiu's and Reaumur's thermometers have their zero at the *freesing* point, while the thermometer of Fahrenheit has its zero at that point at which it stands when immersed in a mixture of snow and common salt.